



COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY

NORTHERN REGIONAL OFFICE

Molly Joseph Ward
Secretary of Natural Resources

13901 Crown Court, Woodbridge, Virginia 22193
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David K. Paylor
Director

Thomas A. Faha
Regional Director

January 12, 2017

Ms. Paula Hamel
Director – Generation Environmental Services
Dominion Resources Services, Inc.
5000 Dominion Boulevard
Glen Allen, VA 23060

Re: Revised Concept Engineering Report – Internal Outfall 503 Wastewater Treatment System
Virginia Pollutant Discharge Elimination System (VPDES) Permit No. VA0002071
Dominion – Possum Point Power Station

Dear Ms. Hamel:

The Concept Engineering Report (CER) received under cover letter dated December 2, 2016, and revised December 19, 2016, for the above referenced project is approved. This action is in accordance with a memorandum dated January 12, 2017, a copy of which is enclosed for your information.

The Department of Environmental Quality (DEQ) approval does not relieve you of your responsibility to:

1. Construct the treatment system in accordance with the approved CER;
2. Operate the treatment system in a manner to consistently meet the facility's performance requirements;
3. Correct design and/or operation deficiencies; or
4. Comply with all other applicable laws and regulations.

Part I.F.22 of the facility's VPDES permit requires that no later than 14 days following completion of construction of any project for which a CER has been approved, written notification shall be submitted to the DEQ – Northern Regional Office certifying, that based on an inspection of the project, construction was completed in accordance with the approved CER.

Nothing in this CER approval preempts, modifies, or otherwise alters any effluent limitations or monitoring requirements within VPDES Permit No. VA0002071.

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VA0002071
Concept Engineering Report Approval
January 12, 2017
Page 2 of 2

If you have any questions, please contact Susan Mackert at (703) 583-3853 or by E-mail at susan.mackert@deq.virginia.gov

Respectfully,



Bryant Thomas
Water Permits & Planning Manager

Enc.: Concept Engineering Report Memo

Ec: Ken Roller (kenneth.roller@dom.com)
Jason Williams (Jason.E.Williams@dom.com)

00022418

MEMORANDUM

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

NORTHERN REGIONAL OFFICE

13901 Crown Court

Woodbridge, VA 22193

SUBJECT: Revised Concept Engineering Report
Internal Outfall 503 Wastewater Treatment System
VA0002071 - Dominion – Possum Point Power Station

TO: Bryant Thomas

FROM: Susan Mackert

DATE: January 12, 2017

COPIES: Paula Hamel – Dominion
Jason Williams – Dominion
Ken Roller – Dominion

Project Name: Revised Concept Engineering Report – Internal Outfall 503 Wastewater Treatment System

Project Owner: Virginia Electric and Power Company d/b/a Dominion Virginia Power

Project Scope: The revised Concept Engineering Report dated December 2, 2016, and December 19, 2016, revision describes enhancements to the Internal Outfall 503 Wastewater Treatment System to optimize and customize the treatment system treating the ash pond dewatering operations prior to discharge.

Previous Agency

Action: The Concept Engineering Report for the Internal Outfall 503 Wastewater Treatment System was approved on April 1, 2016.

The Concept Engineering Report for the Internal Outfall 503 Wastewater Treatment System was revised July 2015, and subsequently approved on July 25, 2016.

Staff Comments: Staff has no objections to the wastewater treatment system as proposed in Dominion's submittal dated December 19, 2016.

A separate Concept Engineering Report for the treatment system designed and operated to treat final configuration (post-construction) wastewaters shall be required.

Staff Recommendation: Staff recommends that the December 2016 revised Concept Engineering Report be approved.

00022419

Overnight Mail
Return Receipt Requested

December 19, 2016

Ms. Susan Mackert
Senior Water Permit Writer
Virginia Department of Environmental Quality
Northern Regional Office
13901 Crown Court, Woodbridge, VA 22193

**RE: Dominion Possum Point Power Station VPDES Permit No. VA0002071:
Revised CER for Centralized Source Water Treatment System**

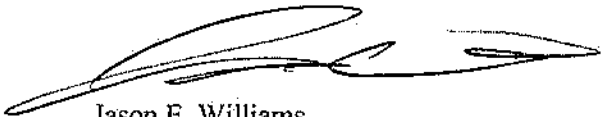
Dear Ms. Mackert:

Enclosed is a revised Concept Engineering Report (CER) for the Internal Outfall 503 Wastewater Treatment System that Dominion is planning to utilize to treat wastewaters generated during the ash pond closure project at the Possum Point Power Station. Dominion has applied numerous lessons learned after operating the Possum Point treatment system for over six months. As a result, we have identified a number of potential enhancements that will optimize and customize the treatment system to further reduce effluent concentrations in the ash pond dewatering discharges. As demonstrated by our weekly and monthly data submittals, all discharges have been well below the permit effluent limits. However, the system enhancements requested in this revised CER are expected to further improve the system's efficiency.

Please contact Ken Roller of my staff at (804) 273-3494 or by email at kenneth.roller@dom.com should you have any questions or require additional information about this transmittal.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Sincerely,



Jason E. Williams
Manager, Generation Environmental Services



Concept Engineering Report

Internal Outfall 503 Wastewater Treatment System

A world of
capabilities
delivered locally

CONCEPT ENGINEERING REPORT

INTERNAL OUTFALL 503 WASTEWATER TREATMENT SYSTEM

Possum Point Power Station



Dominion

Submitted To: Virginia Electric and Power Company
5000 Dominion Boulevard
Glen Allen, VA 23060-3308

Submitted By: Golder Associates Inc.
2108 W. Laburnum Avenue
Suite 200
Richmond, VA 23227



December 2016 (Rev. 3)

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1.0 INTRODUCTION

This Concept Engineering Report (CER) revision has been prepared to optimize the Internal Outfall 503 Wastewater Treatment System at Dominion's Possum Point Power Station (Station), located in Dumfries, Prince William County, Virginia. The Station converted from a coal-fired power plant to an oil- and natural gas-fired power plant in 2003. Coal Combustion Residuals (CCR) from historical coal-fired operations are stored in five impoundments on-site (Ash Ponds A, B, C, D, and E).

The CER was originally submitted to the Virginia Department of Environmental Quality (DEQ) in March 2016, and was approved by the DEQ on April 1, 2016. The treatment system was constructed in accordance with the CER, and written notification that the construction was completed in accordance with the CER was certified by a professional engineer and provided to the DEQ in accordance with Special Condition I.F.22 of the Station's Virginia Pollutant Discharge Elimination System (VPDES) Permit No. VA0002071 (VPDES Permit). An Addendum to the original CER was submitted to the VDEQ in July 2016, and was approved by the VDEQ on July 25, 2016. The purpose of this revision to the CER is to optimize the wastewater treatment system design and operational concepts presented in the original CER, as well as in the Addendum.

Dominion is in the process of closing the five CCR surface impoundments at the Station in accordance with the U.S. Environmental Protection Agency's (EPA's) final CCR rule, which is codified in 40 CFR §257, and which has also been adopted by reference into the Virginia Solid Waste Management Regulations (VSWMR) at 9VAC20-81-10 *et seq.* Closure of Ash Ponds A, B, C, and E will be accomplished by dewatering and removing the CCR. The dewatering process refers to the removal of CCR pore water and stormwater in contact with the CCR. The CCR from Ash Ponds A, B, C, and E may be placed in Ash Pond D in accordance with the VPDES Permit. Ash Pond D will be decanted and dewatered. The decanting process refers to the drawdown, treatment, and discharge of surface waters above the CCR material. Following the dewatering process, Ash Pond D will be converted to a single regulated solid waste facility subject to applicable state and federal closure and post-closure care requirements. The closure of Ash Pond D will be accomplished by regrading, capping, and closing the CCR in place. During the closure activities for all ponds, wastewater may be generated and will require treatment to ensure compliance with the limitations and conditions in the VPDES Permit, which was modified by the State Water Control Board on January 19, 2016. Wastewater generated during the closure of Ash Ponds A, B, C, D, and E will be directed to the wastewater treatment system, which will be monitored at Internal Outfall 503. Dominion has prepared this CER to provide a description of the Internal Outfall 503 Wastewater Treatment System, which has been specifically designed to comply with the numeric effluent limitations in Part I.A.13 of the VPDES Permit. The Internal Outfall 503 Wastewater Treatment System was brought on-line and operated following DEQ approval of the original CER.

The conceptual engineering systems and processes presented herein reflect the planned conceptual approach for the Internal Outfall 503 Wastewater Treatment System and may not reflect the specific details of the final design system configuration. After installation of the system optimizations detailed in this report, a certification will be provided in writing that, based on inspection of the project, the Internal Outfall 503 Wastewater Treatment System construction was completed in general accordance and intent with this CER.

1.1 Site Description

Possum Point Power Station is owned and operated by Virginia Electric and Power Company doing business as Dominion Virginia Power (Dominion). The Station is located in Prince William County, Virginia, at 19000 Possum Point Road, just east of Route 1 (Jefferson Davis Highway) and west of the Potomac River. The location of the Station and the Station's outfalls are illustrated on an aerial photograph as Drawing 1. The Station property is located on a peninsula and consists of wooded, open, and developed land west of the Potomac River. The property is zoned A-1 (agriculture) and M-1 (mixed industrial). The southern and western boundaries of the Station's property are bordered by Quantico Creek, which flows directly into the Potomac River. Adjoining land to the west and north of the Station is generally undeveloped and wooded, and zoned for Planned Mixed Residential (PMR) use. Areas further west and north are in residential use.

A site plan with the water treatment system's primary location is presented on an aerial photograph as Drawing 2a. However, Internal Outfall 503 Wastewater Treatment System may need to be moved in order to facilitate the closure of Ash Pond D. A site plan with an alternate location for the treatment system is shown on Drawing 2b.

2.0 WASTEWATER SOURCES

The wastewater sources to the treatment system during the closure activities for Ash Ponds A, B, C, D, and E are described below.

Wastewater sources (from Ash Ponds A, B, C, D, and E) will be treated as described in Section 4.0 and subject to the triggers for enhanced treatment as identified in Section 4.2. Treatment system effluent will ultimately be discharged to Outfall 001/002 via Internal Outfall 503. Wastewater sources may be conveyed to Ash Pond D, temporary influent storage tanks, and/or to the start of the treatment system during the closure of the Ash Ponds. Also, wastewaters may be temporarily stored in Ash Ponds A, B, C, and E, as necessary, throughout the closure of the Ash Ponds.

2.1 Pond D Comingled Water

Pond D Comingled Water results from the comingling of a number of wastewater types, historically including, but not limited to: Decant, Dewatering, and Contact Water from Ash Ponds A, B, C, D, and E; discharges from the Metals Cleaning Waste Treatment Facility and Oil Water Treatment Basin; and

stormwater runoff from the surrounding watershed. As an initial step in the process leading to closure of Ash Pond D, it will be necessary to remove the Pond D Comingled Water in order to dewater the CCR enough to allow for preparation of a stable surface on which to construct the closure cap. Pond D Comingled Water will be routed to the Internal Outfall 503 Wastewater Treatment System for treatment and discharge through Internal Outfall 503.

During the decanting stage, Pond D Comingled Water will be decanted from Ash Pond D at a maximum flow rate of 2.88 million gallons per day [2,000 gallons per minute (gpm)], with a drawdown per day in accordance with the VPDES Permit. During the dewatering stage, wastewaters generated will likely be less than those produced during the decanting stage, and therefore, the discharges from the Internal Outfall 503 Wastewater Treatment System may be intermittent during that phase of the closure project.

2.2 Ash Pond Contact Stormwater

Ash Pond Contact Stormwater is stormwater that has contacted the CCR in Ash Ponds A, B, C, D, and E and is considered process wastewater. This waste stream will be directed to the Internal Outfall 503 Wastewater Treatment System for treatment prior to discharge through Internal Outfall 503.

2.3 Ash Pond Ash Dewatering Water

Ash Pond Ash Dewatering Water is considered to be the pore water within the CCR mass in Ash Ponds A, B, C, D, and E. This wastewater refers to the water that is produced from dewatering the CCR to stabilize the CCR and allow for its removal by mechanical dredging or excavation (Ash Ponds A, B, C, and E), or to support the closure cap system (Ash Pond D). The wastewater is generated from the CCR dewatering process through mechanical means (e.g., vacuum wells, sump pumps, or other *in situ* withdrawal methods) and from cutting drainage ditches or rim ditches into the CCR mass. Ash Pond Ash Dewatering Water will be directed to the Internal Outfall 503 Wastewater Treatment System for treatment prior to discharge through Internal Outfall 503.

3.0 WASTEWATER CHARACTERISTICS

To characterize the expected quality of most wastewater sources to be treated in the Internal Outfall 503 Wastewater Treatment System, a series of sampling events was conducted between May and November 2015 by GAI Consultants. During these events, samples were collected from representative locations within the source streams for various analyses. Samples were analyzed by a Virginia Environmental Laboratory Accreditation Program (VELAP)-certified laboratory for metals, total suspended solids (TSS), and other constituents subject to numeric effluent limitations per the VPDES Permit. The results of the laboratory analyses for those constituents are presented in Tables 1 through 3 and summarized in Table 4 (prepared by GAI Consultants).

Pond D Comingled Water Samples were collected on November 6 and 13, 2015. These samples are representative of the expected water quality of Pond D Comingled Water prior to any additional treatment. It is anticipated that pollutant concentrations will increase as Pond D Comingled Waters are drawn down during the decanting stage. The sample results were compared with the VPDES Permit limits for Internal Outfall 503 and shown in Table 1. The sample results indicate that the water quality for Ash Pond D Comingled Water is below the VPDES Permit limits.

Ash Pond Ash Dewatering Water samples were collected in May 2015 from several rim ditch and well point discharge locations in Ash Pond E. Additionally, a sample of well point discharges from Ash Pond E was collected by the Prince William County Service Authority (PWCSA) in July 2015 for separate analysis. The samples collected from Ash Pond E are representative of the expected water quality of dewatering waters. The water quality data compared with the VPDES Permit limits for Internal Outfall 503 is shown in Table 2. The sample results indicate elevated metals concentrations (total) for certain metals, as well as TSS, in one or more of the representative Ash Pond Ash Dewatering Water samples. The elements with elevated concentrations, as compared to the VPDES Permit limits, are: arsenic, copper, lead, nickel, selenium, and thallium. Levels of arsenic above the VPDES Permit limits were found in seven of the eight samples. In addition, four of the eight Ash Pond Ash Dewatering Water samples had elevated TSS concentrations in comparison to the VPDES Permit limits, contributing to the elevated total metals concentrations.

To characterize Ash Pond Contact Stormwater, a sample was collected from Ash Pond E on May 5, 2015. Table 3 presents the analytical results, as compared to the VPDES Permit limits. The constituents with a concentration exceeding the effluent VPDES Permit limits are TSS and total selenium.

4.0 TREATABILITY

In order to design a system that achieves design treatment and effluent concentrations in accordance with the VPDES Permit, the wastewater treatment contractor ProAct Services Corporation (ProAct) completed on-site treatability studies (refer to Appendix A). The first treatability study was performed to pre-select polymers to aid in metals removal for chemical addition/flocculation and settling unit processes. This study for Possum Point evaluated solids removal efficiencies of a number of pre-selected cationic and anionic polymer applications suitable for the water quality and constituent levels anticipated for dewatering waters during the pond closure project. Polymers that worked most effectively given the ash pond water quality characteristics were recommended for implementation, and dosage ranges were provided to allow for operational flexibility. The conclusion of ProAct's first study suggested that a large majority of metals and solids removal would be efficiently managed with aeration (as needed), chemical addition, coagulation/flocculation/settling, filtration, and adsorption unit processes. An ion-exchange resin for final metals polishing was recommended, as needed. The second treatability study examined chemical, physical, and media enhancements that could be added to the existing treatment system (designed based on the first treatability study) to decrease targeted constituent levels found in the system (refer to Appendix

B). The study found that by increasing the levels of approved chemicals in the system and using proposed chemical alternatives as needed, constituent levels could be dropped significantly. This includes a proposed chemical injection during the enhanced treatment process. These proposed chemical changes resulted in needed physical changes to the treatment system, such as the addition of plate clarifiers, deep bed sand filters, and post-treatment aeration. The study also compared the effectiveness of different adsorptive medias and resins and proposed a list of recommendations for use.

The Internal Outfall 503 Wastewater Treatment System is designed based on the results of the treatability studies, published literature, and operational experience. A treatment process flow diagram illustrating the conceptual treatment system design is shown in Drawing 3. The decision about which processes will be run on any given day will be made based on influent quality and/or best professional judgement to maximize treatment. The initial conceptual treatment system design basis and Equipment General Arrangement are included in Appendix A.

4.1 Treatment Process

Raw source water and/or recirculated treated wastewaters will be conveyed to the aeration tanks. The aeration tanks are 21,000-gallon (nominal) tanks. Air will be injected into the aeration tanks via electric blowers in order to oxidize the dissolved metals. The blowers used with the aeration tanks may be turned on or off as needed for treatment. Prior to the tanks, chemical additions may be necessary to maximize treatment. A list of chemicals that may be used (as needed) in the treatment process is provided in Table 5. Any chemical listed in Table 5 may be added at any location in the treatment system to enhance treatment and/or maintain the effluent limitations [*i.e.*, pH within the range of 6-9 Standard Units (SU)]. Water from the aeration tanks may then be pumped to the polymer injection trailers.

The polymer injection trailers have automatic injection capabilities for coagulation and flocculation. The polymers that may be used for either of these functions are listed in Table 5. Coagulation is used to change the electrical charge of the fine particles and to cause a destabilization of the particles. Flocculation is used to bring the charged particles together and to make them heavier, which allows for better settling out of the particles. Flocculent and coagulant dosing and usage will be determined based on the results of on-going process jar tests. The trailers also include an in-line static mixer after polymer injection for continuous mixing of the water and polymer additions.

Water is then conveyed to settling tanks for removal of flocculants. Inclined plate clarifiers may be used to optimize removal of built-up iron-based hydroxides by providing increased settling surface area and shorter settling distance than conventional settling tanks.

Solids generated in the inclined plate clarifiers will collect in the hopper of the clarifiers and will be transferred into geotube boxes containing engineered geotextile bags that will retain the solids. The solids may then be emptied into Pond D. Used geotextile bags will be hauled off-site for disposal in a permitted

landfill. The geotube decant water may be recycled to Ash Pond D, the optional influent storage tanks, or back to the start of the treatment system.

After the settling tanks, treated water may either be recirculated or pumped to the sand filters.

The sand filter system consists of vessels containing deep-bed sand filters, or equivalent. Using the sand filtration system, small flocculants that pass through the settling tanks will be removed. The sand filters will be backwashed to help clear build-up of particles removed from the process water. The backwash water may be recycled to Ash Pond D, the optional influent storage tanks, or back to the start of the treatment system.

Water from the sand filters may then travel to a bag filter system designed to remove TSS, sediment, and filterable metals from the process water prior to discharge. The filters may be run in series or parallel, and the micron rating of the bag filters may be selected depending on treatment needs. Spent bag filters will be hauled off-site for disposal in a permitted landfill.

After the first bag filter system, the treated water passes through an in-line process sampling point (S1). In-line process samples will be collected at a minimum frequency of once every hour at an in-line process sampling point (S1), and analytical results will be returned within approximately one (1) hour after sample collection. This sampling is in addition to the effluent compliance sampling required by the VPDES Permit.

PH adjustment may occur before the water moves on to a second bag filter system. The chemicals that may be added are listed in Table 5. The second bag filter system will utilize high efficiency filters as a preventative measure to catch remaining particulates in the process water. The micron rating of the bag filters may be selected depending on treatment needs, and the spent bag filters will be hauled off-site for disposal in a permitted landfill. From the second bag filter system, water may be conveyed through Venturi tubes or aeration tanks to adjust final dissolved oxygen levels in the treated water. The aeration may be turned on or off as needed for treatment. The treated water may then be directed to effluent pump wet well tanks before being pumped on to the optional effluent storage tanks.

Sampling of the final effluent will be conducted in accordance with the VPDES Permit to comply with Parts I.A.13 and I.C.2. Storage capacity for the effluent from the Internal Outfall 503 Wastewater Treatment System may be provided to effectively manage the wastewater, as described in Section 5.0. The storage of treated wastewater in temporary effluent storage tanks allows Dominion the option to sample and analyze the water to ensure VPDES Permit compliance prior to discharge to Internal Outfall 503. Internal Outfall 503 will be metered and sampled for compliance with the VPDES Permit. If effluent storage is used, effluent monitoring for compliance with the VPDES Permit will be performed on the effluent from the storage vessel(s). From Internal Outfall 503, effluent will be routed to Outfall 001/002 for ultimate discharge.

4.2 Enhanced Treatment (if necessary)

Enhanced treatment includes chemical addition, adsorptive media vessels, and ion-exchange resin, as necessary, for improved constituent removal. While the treatment system is running, in-line process samples will be collected at a minimum frequency of once every hour at an in-line process sampling point (S1), and analytical results will be returned within approximately one (1) hour after sample collection. This sampling is in addition to the effluent compliance sampling required by the VPDES Permit. If effluent from the treatment system exceeds any of the trigger concentrations presented below, as determined by the in-line process sampling and analysis from the in-line process sampling point (S1), then the effluent will be routed through enhanced treatment. In order to maximize treatment and provide targeted constituent removal, each step of enhanced treatment may be used as needed. However, when effluent is routed through enhanced treatment, at least one component of enhanced treatment as described in this section will be used. The trigger concentrations are as follows:

- Arsenic – 100 micrograms per liter (ug/L)
- Antimony – 640 ug/L
- Selenium – 5.0 ug/L
- Thallium – 0.47 ug/L
- Lead – 7.4 ug/L
- Copper – 6 ug/L

The enhanced treatment can likewise be turned off should the in-line process sampling and analysis determine that concentrations prior to the enhanced treatment system are below the trigger limits. Dominion reserves the right to operate any component of the enhanced treatment system at any time even if trigger limits have not been exceeded.

A monthly report will be submitted to the DEQ, which will provide dates and times when enhanced treatment was turned on or off and a summary of why the enhanced treatment was turned on or off. The in-line process samples will be grab samples and will be analyzed using methods that will achieve the Quantification Levels (QLs) specified in the VPDES Permit.

Enhanced treatment can occur directly after the first set of bag filter systems. Water may first be directed to optional vessels set up to run in series or in parallel depending on treatment needs. These vessels may be filled with granular activated carbon used as a pretreatment filtration media to help lower the dissolved oxygen levels in the water and/or FilterGlass.

After the granular activated carbon vessels, the treated water will pass through a chemical injection point. A list of chemicals that may be injected are included in Table 5. The treated water may then be routed to adsorptive media vessels for enhanced treatment, as needed, which can contain granular activated alumina. The vessels will be set up to run in series or in parallel, depending on treatment needs. After the

activated alumina vessels, water may be directed to additional adsorption and/or ion exchange processes for additional enhanced treatment (depending on the in-line process sample results) or the second set of bag filters.

Based on water quality analyses, water may be conveyed to additional adsorption and/or ion exchange treatment processes to provide additional selective constituent removals, as needed. Two systems are proposed that consist of vessels that may be run in parallel or series. The first system may be filled with adsorptive media or resin for targeted constituent removal based on the needs of the treatment system. The second system may be filled with ion exchange resin specific to the desired constituent removals. Adsorptive media may be placed in the headspace of each ion exchange unit, if desired, to enhance treatment. A list of medias and resin that may be used for enhanced treatment is provided in Table 6. Backwashing may be used to prolong the life of the medias and resins used during enhanced treatment by cleaning out built up particulates. Backwash wastewater may be recirculated to Ash Pond D, the influent storage tanks, and/or to the start of the treatment system.

Periodic sampling of the effluent from the adsorptive media vessels and/or ion exchange resin vessels throughout the enhanced treatment process may be used to determine if dissolved metals breakthrough is occurring. This sampling may be used to determine when to replace the medias and/or resins, as well as the effectiveness of the enhanced treatment components.

5.0 STORAGE TANKS

Temporary effluent storage tanks optionally will be used to provide hydraulic retention of treated effluent prior to discharge. Four 950,000-gallon temporary aboveground storage tanks may be erected to provide a storage capacity of up to 3,800,000 gallons (Drawing 4). The storage tanks will be erected in Ash Pond E and set on a compacted aggregate base. The inside of the tanks will be lined with a geomembrane liner for water-tight containment, and the prepared area will be provided with spill containment.

The temporary storage tanks will be used in conjunction with the Internal Outfall 503 Wastewater Treatment System. The tanks will be operated in rotation to hold approximately 12 hours of treated effluent at an approximate operating rate of up to 1,500 gallons per minute. Internal Outfall 503 will be the metered outfall compliance sampling location.

Process monitoring may be performed on the influent side of the tanks and/or within the tanks at various times to confirm the Internal Outfall 503 Wastewater Treatment System is operating as designed to meet the permitted effluent limits prior to discharge. In the event that the process monitoring indicates the designed level of treatment is not being achieved, the stored effluent can then be recirculated through the system for additional treatment, recirculated to the optional influent tanks, or recirculated back to Ash Pond D.

Effluent tanks may be repurposed as influent storage tanks to accommodate periods of low-flow operations or peak contact stormwater generation to effectively manage influent water quantities. An optional influent line can be used to transfer wastewater sources as described in Section 2.0 to the optional influent storage tanks. The recirculation line can be used to transfer stored influent to the Internal Outfall 503 Wastewater Treatment System.

TABLES

Table 1
Possum Point Pond D Comingled Water Compared with VPDES Permit Limits for Internal Outfall 503

Parameters	Units	VPDES Permit Limits				Pond D Comingled Water									
		Internal Outfall 503 - When Routed to 001/002 or 004				Pond D 6A	Pond D 6B	Pond D 6C	Pond D 7A	Pond D 7A	Pond D 7B	Pond D 7C	Pond D 8A	Pond D 8B	Pond D 8C
		Monthly Average	Daily Maximum	Minimum	Maximum	11/6/15	11/6/15	11/6/15	11/6/15	11/13/15	11/13/15	11/13/15	11/13/15	11/13/15	11/13/15
pH ⁽¹⁾	S.U.	N/A	N/A	6.0	9.0	7.97	7.93	7.86	7.94	NA	7.74	7.85	7.79	7.74	7.78
Total Suspended Solids (TSS)	mg/L	30	100	N/A	N/A	< 5	< 5	< 5	< 5	NA	< 5	< 5	< 5	< 5	5
Oil and Grease (O&G)	mg/L	15	20	N/A	N/A	4.0	4.6	5.0	6.9	NA	0.51±	< 2.1	< 2.0	< 2.0	< 2.0
Aluminum, Total	ug/L	NL	NL	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aluminum, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Antimony, Total	ug/L	1,300	1,300	N/A	N/A	4.1	4.1	3.8	3.9	NA	3.8	3.8	3.7	4.0	3.7
Antimony, Dissolved	ug/L	N/A	N/A	N/A	N/A	4.1	3.9	4.0	3.7	4.1	3.8	3.8	3.7	3.8	3.7
Arsenic, Total	ug/L	240	440	N/A	N/A	17	17	15	17	NA	16	15	16	16	15
Arsenic, Dissolved	ug/L	N/A	N/A	N/A	N/A	16	15	15	15	15	15	14	14	15	15
Barium, Total	ug/L	NL	NL	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Barium, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Beryllium, Total	ug/L	NL	NL	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Beryllium, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Boron, Total	ug/L	NL	NL	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Boron, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium, Total	ug/L	1.4	2.6	N/A	N/A	< 0.50	< 0.50	< 0.50	< 0.50	NA	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Cadmium, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Chloride	µg/L	370,000	670,000	N/A	N/A	73,600	73,700	74,100	73,400	NA	75,500	75,800	76,200	76,100	76,300
Chromium III, Total	ug/L	88	160	N/A	N/A	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Chromium III, Dissolved ⁽²⁾	ug/L	N/A	N/A	N/A	N/A	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Chromium VI, Total ⁽³⁾	µg/L	17	32	N/A	N/A	0.14±	0.14±	0.14±	0.13±	0.086±	0.089±	0.086±	0.098±	0.086±	0.084±
Chromium VI, Dissolved	µg/L	N/A	N/A	N/A	N/A	0.12±	0.11±	0.12±	0.11±	< 0.25	< 0.25	< 0.25	0.072±	< 0.25	< 0.25
Cobalt, Total	µg/L	NL	NL	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper, Total	µg/L	9.6	18	N/A	N/A	1.9±	1.8±	1.6±	1.7±	NA	0.97±	0.90±	0.87±	0.87±	< 2.5
Copper, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Iron, Total	ug/L	NL	NL	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Iron, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead, Total	µg/L	14	26	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	NA	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Lead, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Mercury, Total	µg/L	1.2	2.2	N/A	N/A	< 0.20	< 0.20	< 0.20	< 0.20	NA	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Mercury, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 0.20	0.35	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20

Table 1 (continued)
Possum Point Pond D Comingled Water Compared with VPDES Permit Limits for Internal Outfall 503

Parameters	Units	VPDES Permit Limits				Pond D Comingled Water									
		Internal Outfall 503 - When Routed to 001/002 or 004				Pond D 6A	Pond D 6B	Pond D 6C	Pond D 7A	Pond D 7A	Pond D 7B	Pond D 7C	Pond D 8A	Pond D 8B	Pond D 8C
		Monthly Average	Daily Maximum	Minimum	Maximum	11/6/15	11/6/15	11/6/15	11/6/15	11/13/15	11/13/15	11/13/15	11/13/15	11/13/15	11/13/15
Molybdenum, Total	µg/L	NL	NL	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Molybdenum, Dissolved	µg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nickel, Total	µg/L	24	44	N/A	N/A	5.5	5.3	4.9	5.5	NA	4.9	4.8	4.5	4.6	4.4
Nickel, Dissolved	µg/L	N/A	N/A	N/A	N/A	4.6±	5.3	4.5±	4.6±	4.6±	4.5±	4.5±	4.2±	4.7±	4.3±
Selenium, Total	µg/L	8.0	15	N/A	N/A	7.4	6.7	6.3	6.7	NA	5.6	5.4	5.6	5.7	5.4
Selenium, Dissolved	µg/L	N/A	N/A	N/A	N/A	6.3	5.2	6.3	5.4	6.4	5.8	5.9	6.1	5.8	6.3
Silver, Total	µg/L	2.2	4.0	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	NA	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Silver, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Thallium, Total	µg/L	0.94	0.94	N/A	N/A	0.38±	0.39±	0.35±	0.38±	NA	0.40±	0.39±	0.39±	0.40±	0.37±
Thallium, Dissolved	µg/L	N/A	N/A	N/A	N/A	0.48±	0.40±	0.39±	0.39±	0.42±	0.39±	0.37±	0.36±	0.37±	0.39±
Vanadium, Total	µg/L	NL	NL	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium, Dissolved	µg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zinc, Total	µg/L	98	180	N/A	N/A	< 2.5	0.91±	< 2.5	< 2.5	NA	< 2.5	< 2.5	< 2.5	< 2.5	< 2.5
Zinc, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0	6.8	< 5.0	3.9±	< 5.0	< 5.0	< 5.0	< 5.0	5.3	< 5.0
Hardness, Total (as CaCO ₃)	mg/L	NL	NL	N/A	N/A	150	150	159	158	NA	155	155	154	157	144
Total Nitrogen	mg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Kjeldahl Nitrogen	mg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrate+Nitrite (NO ₃ +NO ₂), as N	mg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ammonia, as N	mg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acute Toxicity – <i>C. dubia</i> ⁽⁴⁾	% NOEC	N/A	N/A	100%	N/A	NA	NA	100%	NA	NA	NA	NA	NA	NA	NA
Acute Toxicity – <i>P. promelas</i> ⁽⁴⁾	% NOEC	N/A	N/A	100%	N/A	NA	NA	100%	NA	NA	NA	NA	NA	NA	NA
Chronic Toxicity – <i>C. dubia</i> ⁽⁵⁾	TU _c	N/A	N/A	N/A	2.85	NA	NA	1.0	NA	NA	NA	NA	NA	NA	NA
Chronic Toxicity – <i>P. promelas</i> ⁽⁵⁾	TU _c	N/A	N/A	N/A	2.85	NA	NA	1.0	NA	NA	NA	NA	NA	NA	NA

Footnotes:

- ¹Values preceded by "<" represent results not detected at the Reporting Detection Limit (RDL) and listed as < RDL.
- ²Values with suffix "±" represent results with an estimated value between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL) for the analyte.
- ³NA- Not analyzed.
- ⁴mg/L - milligrams per liter.
- ⁵µg/L- micrograms per liter.
- ⁶NL = No Limit.
- ⁷Reported as No Observed Effect Concentration (NOEC); 100 percent NOEC is required for Acute Toxicity tests.
- ⁸Reported as Chronic Toxicity Units; A maximum of 2.85 Chronic Toxicity Units allowed for Chronic Toxicity Results.
- ⁹VPDES Permit limits for comparison are for the discharge of Outfall 503 to Outfall 001/002.
- ¹⁰Where Reporting Detection Limit (RDL) of dissolved metals exceeds total metals, the lab diluted the sample to obtain a result thus increasing the Limit of Quantitation (LOQ) and RDL by the factor of dilution.

Table 2
Possum Point Dewatering Water Compared with VPDES Permit Limits for Internal Outfall 503

Parameters	Units	VPDES Permit Limits				Pond E Rim Ditch			Pond E Well Points					
		Internal Outfall 503 - When Routed to 001/002 or 004				RMD-1	RMD-2	RMD-3	Well Discharge 1	Well Discharge 2	Well Discharge 3	Well Discharge 3 dup	PWCSA Sample	GAI Duplicate Sample
		Monthly Average	Daily Maximum	Minimum	Maximum	5/5/2015	5/6/2015	5/11/2015	5/11/2015	5/12/2015	5/13/2015	5/13/2015	7/30/2015	7/30/2015
pH ⁽¹⁾	S.U.	N/A	N/A	6.0	9.0	7.85	8.00	8.08	7.77	7.88	7.76	7.81	8.15	7.32
Total Suspended Solids (TSS)	mg/L	30	100	N/A	N/A	26	159	44	34	19	20	26	42	27
Oil and Grease (O&G)	mg/L	15	20	N/A	N/A	< 2.0	1.7±	1.1±	1.4±	< 2.0	< 2.0	< 2.0	NA	NA
Aluminum, Total	ug/L	NL	NL	N/A	N/A	NA	17,800	NA	NA	59	NA	NA	NA	NA
Aluminum, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	260	NA	NA	< 80	NA	NA	NA	NA
Antimony, Total	ug/L	1,300	1,300	N/A	N/A	4.3	14	2.7	< 1.0	< 1.0	< 1.0	< 1.0	NA	NA
Antimony, Dissolved	ug/L	N/A	N/A	N/A	N/A	3.9	16	2.5	< 2.0	< 2.0	< 2.0	< 2.0	NA	NA
Arsenic, Total	ug/L	240	440	N/A	N/A	51	370	260	1,100	920	1,200	1,200	390	330
Arsenic, Dissolved	ug/L	N/A	N/A	N/A	N/A	24	240	180	880	810	900	840	< 50	51
Barium, Total	ug/L	NL	NL	N/A	N/A	220	830	290	400	330	420	410	NA	NA
Barium, Dissolved	ug/L	N/A	N/A	N/A	N/A	180	250	240	370	360	380	360	NA	NA
Beryllium, Total	ug/L	NL	NL	N/A	N/A	NA	7.2	NA	NA	< 0.50	NA	NA	< 4.0	0.30±
Beryllium, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	0.11±	NA	NA	< 1.0	NA	NA	< 50	0.18±
Boron, Total	ug/L	NL	NL	N/A	N/A	NA	1,000	NA	NA	1,300	NA	NA	NA	NA
Boron, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	1,000	NA	NA	1,400	NA	NA	NA	NA
Cadmium, Total	ug/L	1.4	2.6	N/A	N/A	< 0.5	0.55	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 50	0.27±
Cadmium, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 50	< 1.0
Chloride	µg/L	370,000	670,000	N/A	N/A	176,000	191,000	173,000	234,000	251,000	247,000	240,000	NA	NA
Chromium III, Total	ug/L	88	160	N/A	N/A	NA	NA	0.90±	< 1.0	< 1.0	< 1.0	< 1.0	< 50	< 1.0
Chromium III, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 10	NA	0.95±	2.6	2.4	2.5	2.5	< 50	2.0±
Chromium VI, Total	µg/L	17	32	N/A	N/A	0.096±	0.069±	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	NA	NA
Chromium VI, Dissolved	µg/L	N/A	N/A	N/A	N/A	0.095±	0.072±	NA	NA	< 0.25	< 0.25	< 0.25	NA	NA
Cobalt, Total	µg/L	NL	NL	N/A	N/A	NA	16	NA	NA	1.8±	NA	NA	NA	NA
Cobalt, Dissolved	ug/L	N/A	N/A	N/A	N/A	NA	< 5.0	NA	NA	2.2±	NA	NA	NA	NA
Copper, Total	µg/L	9.6	18	N/A	N/A	3.6	84	4.7	1.0±	< 2.5	0.85±	0.84±	< 50	2.1±
Copper, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0	< 5.0	1.9±	< 5.0	< 5.0	1.6±	< 5.0	< 50	1.9±
Iron, Total	ug/L	NL	NL	N/A	N/A	1,700	8,600	980	11,200	10,300	11,800	11,600	NA	NA
Iron, Dissolved	ug/L	N/A	N/A	N/A	N/A	48±	< 60	< 60	5,600	4,900	7,100	6,900	NA	NA
Lead, Total	µg/L	14	26	N/A	N/A	0.95±	38	1.7	< 1.0	< 1.0	< 1.0	< 1.0	< 50	< 1.0
Lead, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 50	< 2.0
Mercury, Total	µg/L	1.2	2.2	N/A	N/A	< 0.2	0.51	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Mercury, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 0.2	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Molybdenum, Total	µg/L	NL	NL	N/A	N/A	NA	50	NA	NA	97	NA	NA	430	400

Table 2 (continued)
Possum Point Dewatering Water Compared with VPDES Permit Limits for Internal Outfall 503

Parameters	Units	VPDES Permit Limits				Pond E Rim Ditch			Pond E Well Points					
		Internal Outfall 503 - When Routed to 001/002 or 004				RMD-1	RMD-2	RMD-3	Well Discharge 1	Well Discharge 2	Well Discharge 3	Well Discharge 3 dup	PWCSA Sample	GAI Duplicate Sample
		Monthly Average	Daily Maximum	Minimum	Maximum	5/5/2015	5/6/2015	5/11/2015	5/11/2015	5/12/2015	5/13/2015	5/13/2015	7/30/2015	7/30/2015
Molybdenum, Dissolved	µg/L	N/A	N/A	N/A	N/A	NA	46	NA	NA	80	NA	NA	370	430
Nickel, Total	µg/L	24	44	N/A	N/A	9.1	28	13	8.1	6.4	8.2	8.0	< 50	7.2
Nickel, Dissolved	µg/L	N/A	N/A	N/A	N/A	6.7	6.5	11	8.0	7.6	7.6	7.5	< 50	7.9
Selenium, Total	µg/L	8.0	15	N/A	N/A	9.3	40	8.8	0.84±	0.81±	1.3±	1.1±	< 50	9.2
Selenium, Dissolved	µg/L	N/A	N/A	N/A	N/A	8.5	25	10	1.8±	1.9±	< 5.0	1.7±	< 50	12
Silver, Total	µg/L	2.2	4.0	N/A	N/A	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	NA	NA
Silver, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	NA	NA
Thallium, Total	µg/L	0.94	0.94	N/A	N/A	0.61	1.4	0.68	< 0.50	< 0.50	< 0.50	< 0.50	NA	NA
Thallium, Dissolved	µg/L	N/A	N/A	N/A	N/A	0.50±	0.65±	0.61±	< 1.0	< 1.0	< 1.0	< 1.0	NA	NA
Vanadium, Total	µg/L	NL	NL	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	< 50	7.2
Vanadium, Dissolved	µg/L	N/A	N/A	N/A	N/A	NA	NA	NA	NA	NA	NA	NA	< 50	< 2.0
Zinc, Total	µg/L	98	180	N/A	N/A	7.3	66	13	26	16	16	16	< 50	6.9
Zinc, Dissolved	µg/L	N/A	N/A	N/A	N/A	8.4	5.4	8.5	12	190	11	12	< 50	36
Hardness, Total (as CaCO₃)	mg/L	NL	NL	N/A	N/A	193	246	231	463	401	417	415	NA	NA
Total Nitrogen	mg/L	N/A	N/A	N/A	N/A	NA	< 1.0	NA	NA	< 1.00	NA	NA	NA	NA
Total Kjeldahl Nitrogen	mg/L	N/A	N/A	N/A	N/A	NA	< 1.0	NA	NA	< 1.0	NA	NA	NA	NA
Nitrate+Nitrite (NO₃+NO₂), as N	mg/L	N/A	N/A	N/A	N/A	< 0.20 ⁽⁴⁾	< 0.40	< 0.20 ⁽⁴⁾	< 0.50 ⁽⁴⁾	< 1.00	< 0.50 ⁽⁴⁾	< 0.50 ⁽⁴⁾	NA	NA
Ammonia, as N	mg/L	N/A	N/A	N/A	N/A	0.058±	0.062±	0.043±	0.306	0.322	0.287	0.282	NA	NA
Acute Toxicity – <i>C. dubia</i> ⁽²⁾	% NOEC	N/A	N/A	100%	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acute Toxicity – <i>P. promelas</i> ⁽²⁾	% NOEC	N/A	N/A	100%	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chronic Toxicity – <i>C. dubia</i> ⁽³⁾	TU_c	N/A	N/A	N/A	2.85	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chronic Toxicity – <i>P. promelas</i> ⁽³⁾	TU_c	N/A	N/A	N/A	2.85	NA	NA	NA	NA	NA	NA	NA	NA	NA

Footnotes:

- ¹ pH values measured in laboratory.
- ² Reported as percent No Observed Effect Concentration (NOEC).
- ³ Reported as Chronic Toxicity Units (TU_c)
- ⁴ Value indicates nitrate (NO₃) only; nitrite was not measured.
- ⁵ Values preceded by "<" represent results not detected at the Reporting Detection Limit (RDL) and listed as < RDL.
- ⁶ Values with suffix "±" represent results with an estimated value between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL) for the analyte.
- ⁷ NA = Not Analyzed
- ⁸ NL = No Limit
- ⁹ N/A = Not Applicable
- ¹⁰ VPDES Permit limits for comparison are for the discharge of Outfall 503 to Outfall 001/002.
- ¹¹ Where Reporting Detection Limit (RDL) of dissolved metals exceeds total metals, the lab diluted the sample to obtain a result thus increasing the Limit of Quantitation (LOQ) and RDL by the factor of dilution.

Table 3
Possum Point Contact Water Compared with VPDES Permit Limits for Internal Outfall 503

Parameters	Units	VPDES Permit Limits				Pond E Contact Water
		Internal Outfall 503 - When Routed to 001/002 or 004				Pond E
		Monthly Average	Daily Maximum	Minimum	Maximum	5/5/2015
pH ⁽¹⁾	S.U.	N/A	N/A	6.0	9.0	7.89
Total Suspended Solids (TSS)	mg/L	30	100	N/A	N/A	39
Oil and Grease (O&G)	mg/L	15	20	N/A	N/A	< 2.0
Aluminum, Total	ug/L	NL	NL	N/A	N/A	1400
Aluminum, Dissolved	ug/L	N/A	N/A	N/A	N/A	110
Antimony, Total	ug/L	1,300	1,300	N/A	N/A	14
Antimony, Dissolved	ug/L	N/A	N/A	N/A	N/A	13
Arsenic, Total	ug/L	240	440	N/A	N/A	90
Arsenic, Dissolved	ug/L	N/A	N/A	N/A	N/A	80
Barium, Total	ug/L	NL	NL	N/A	N/A	210
Barium, Dissolved	ug/L	N/A	N/A	N/A	N/A	160
Beryllium, Total	ug/L	NL	NL	N/A	N/A	< 0.50
Beryllium, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 1.0
Boron, Total	ug/L	NL	NL	N/A	N/A	400
Boron, Dissolved	ug/L	N/A	N/A	N/A	N/A	400
Cadmium, Total	ug/L	1.4	2.6	N/A	N/A	< 0.50
Cadmium, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 1.0
Chloride	µg/L	370,000	670,000	N/A	N/A	72,000
Chromium III, Total	ug/L	88	160	N/A	N/A	< 10
Chromium III, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 10
Chromium VI, Total	µg/L	17	32	N/A	N/A	0.39
Chromium VI, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 0.25
Cobalt, Total	µg/L	NL	NL	N/A	N/A	< 2.5
Cobalt, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 5.0
Copper, Total	µg/L	9.6	18	N/A	N/A	< 6.2
Copper, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0
Iron, Total	ug/L	NL	NL	N/A	N/A	660
Iron, Dissolved	ug/L	N/A	N/A	N/A	N/A	< 60
Lead, Total	µg/L	14	26	N/A	N/A	3.0
Lead, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0
Mercury, Total	µg/L	1.2	2.2	N/A	N/A	< 0.20

Table 3 (continued)
Possum Point Contact Water Compared with VPDES Permit Limits for Internal Outfall 503

Parameters	Units	VPDES Permit Limits				Pond E Contact Water
		Internal Outfall 503 - When Routed to 001/002 or 004				Pond E
		Monthly Average	Daily Maximum	Minimum	Maximum	5/5/2015
Mercury, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 0.20
Molybdenum, Total	µg/L	NL	NL	N/A	N/A	83
Molybdenum, Dissolved	µg/L	N/A	N/A	N/A	N/A	67
Nickel, Total	µg/L	24	44	N/A	N/A	14
Nickel, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 5.0
Selenium, Total	µg/L	8.0	15	N/A	N/A	17
Selenium, Dissolved	µg/L	N/A	N/A	N/A	N/A	19
Silver, Total	µg/L	2.2	4.0	N/A	N/A	< 1.0
Silver, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 2.0
Thallium, Total	µg/L	0.94	0.94	N/A	N/A	0.56
Thallium, Dissolved	µg/L	N/A	N/A	N/A	N/A	< 1.0
Vanadium, Total	µg/L	NL	NL	N/A	N/A	N/A
Vanadium, Dissolved	µg/L	N/A	N/A	N/A	N/A	N/A
Zinc, Total	µg/L	98	180	N/A	N/A	9.1
Zinc, Dissolved	µg/L	N/A	N/A	N/A	N/A	7.8
Hardness, Total (as CaCO₃)	mg/L	NL	NL	N/A	N/A	193
Total Nitrogen	mg/L	N/A	N/A	N/A	N/A	< 1.00
Total Kjeldahl Nitrogen	mg/L	N/A	N/A	N/A	N/A	< 1.0
Nitrate+Nitrite (NO₃+NO₂), as N	mg/L	N/A	N/A	N/A	N/A	< 0.40
Ammonia, as N	mg/L	N/A	N/A	N/A	N/A	0.189
Acute Toxicity – <i>C. dubia</i>⁽²⁾	% NOEC	N/A	N/A	100%	N/A	N/A
Acute Toxicity – <i>P. promelas</i>⁽²⁾	% NOEC	N/A	N/A	100%	N/A	N/A
Chronic Toxicity – <i>C. dubia</i>⁽³⁾	TU_c	N/A	N/A	N/A	2.85	N/A
Chronic Toxicity – <i>P. promelas</i>⁽³⁾	TU_c	N/A	N/A	N/A	2.85	N/A

Footnotes:

- ¹ pH values measured in the field.
- ² Reported as percent No Observed Effect Concentration (NOEC).
- ³ Reported as Chronic Toxicity Units (TU_c)
- ⁴ Values preceded by "<" represent results not detected at the Reporting Detection Limit (RDL) and listed as < RDL.
- ⁵ Values with suffix "±" represent results with an estimated value between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL) for the analyte.
- ⁶ NA = Not Analyzed
- ⁷ NL = No Limit
- ⁸ N/A = Not Applicable
- ⁹ VPDES Permit limits for comparison are for the discharge of Outfall 503 to Outfall 001/002.
- ¹⁰ Where Reporting Detection Limit (RDL) of dissolved metals exceeds total metals, the lab diluted the sample to obtain a result thus increasing the Limit of Quantitation (LOQ) and RDL by the factor of dilution.

Table 4
Identified Constituents for Which Treatment May Be Necessary in Order to Comply with VPDES Permit Limits

Parameter	VPDES Permit Limits for Discharge to Internal Outfall 503 When Routed to Outfall 001/002		Sampling Location	Observed Values
	Monthly Average	Daily Maximum		
Total Selenium (µg/L)	8.0	15	Ash Pond E Dewatering Water	8.8 - 40
			Ash Pond E Contact Water	17
Total Suspended Solids (mg/L)	30	100	Ash Pond E Dewatering Water	27 - 159
			Ash Pond E Contact Water	39
Total Nickel (µg/L)	24	44	Ash Pond E Dewatering Water	28
Total Thallium (µg/L)	0.94	0.94	Ash Pond E Dewatering Water	< 0.50 – 1.4
Total Arsenic (µg/L)	240	440	Ash Pond E Dewatering Water	51 – 1,200
Total Copper (µg/L)	9.6	18	Ash Pond E Dewatering Water	< 2.5 - 84
Total Lead (µg/L)	14	26	Ash Pond E Dewatering Water	< 1.0 - 38

Table 5
Internal Outfall 503 Wastewater Treatment System Process
Chemicals and Polymers
Possum Point Power Station

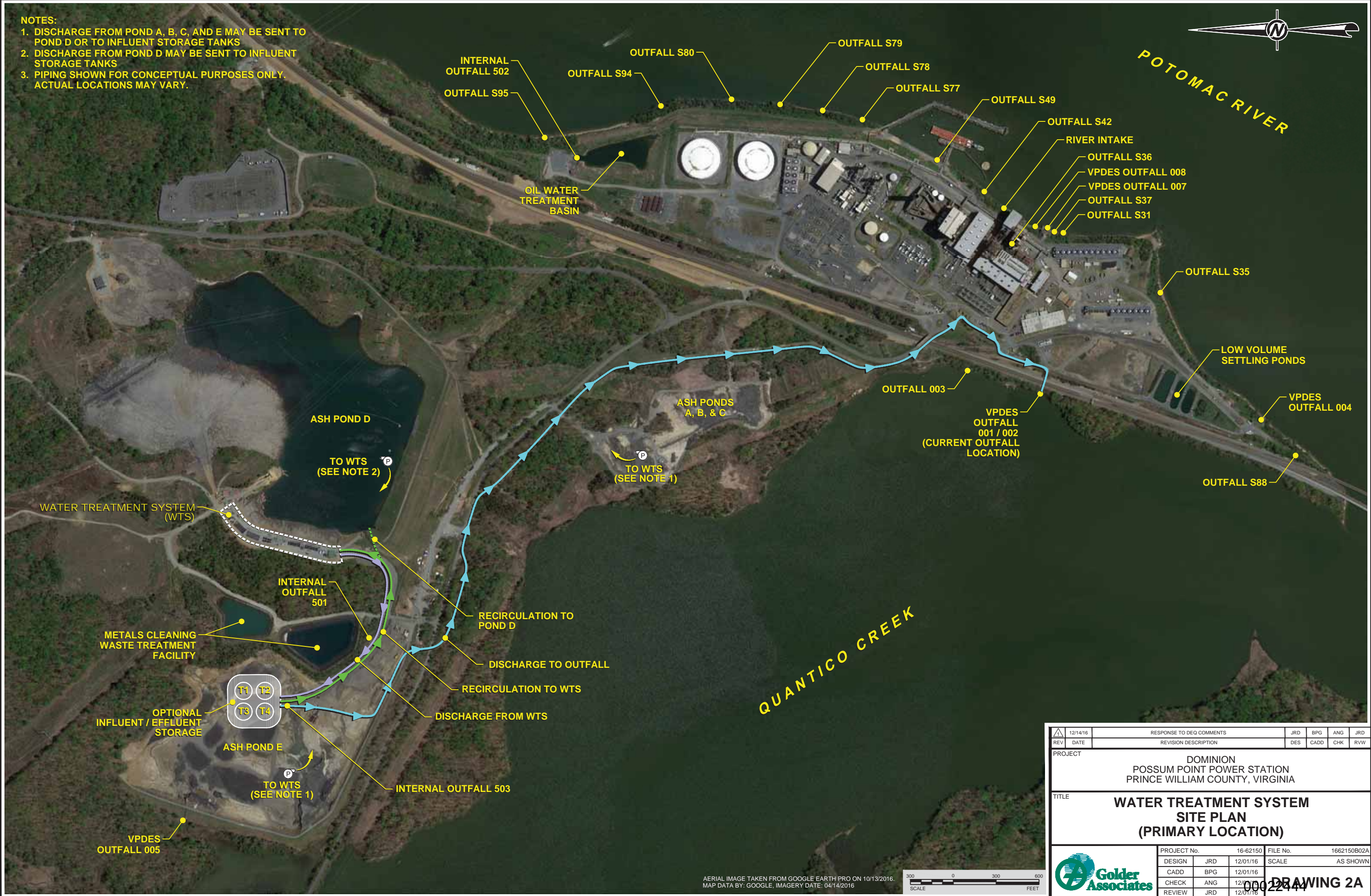
Process Category	Type
<u>Oxidation Chemicals</u>	Sodium Hypochlorite
<u>Coagulants</u>	Ferric Chloride
<u>Flocculants</u>	LBP 2101 BHR-P50 Polyacrylamides
<u>pH Adjustment Chemicals</u>	Caustic Soda Hydrochloric Acid Sulfuric Acid
<u>Reducing Agents</u>	Sodium Sulfite Sodium Metabisulfite Sodium Thiosulfate Calcium Thiosulfate Ascorbic Acid Sodium Ascorbate Ferrous Hydroxide
<u>Precipitation Chemicals</u>	Calcium Hydroxide Barium Chloride Barium Carbonate

Table 6
Internal Outfall 503 Wastewater Treatment System Process
Medias and Resins
Possum Point Power Station

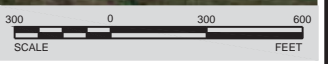
Process Category	Type
<u>Adsorptive Medias</u>	ASG AM Cabot NORIT GAC 830R Zeolite Activated Alumina FilterGlass
<u>Resins</u>	Purolite A-100 weakly basic anion exchange resin ProAct's proprietary resin Purolite FerriX A33E hydrated iron oxide resin Purolite C104NaPlus cation exchange resin



DRAWINGS

- NOTES:
1. DISCHARGE FROM POND A, B, C, AND E MAY BE SENT TO POND D OR TO INFLUENT STORAGE TANKS
 2. DISCHARGE FROM POND D MAY BE SENT TO INFLUENT STORAGE TANKS
 3. PIPING SHOWN FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY.



AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO ON 10/13/2016.
MAP DATA BY: GOOGLE, IMAGERY DATE: 04/14/2016



		12/14/16	RESPONSE TO DEQ COMMENTS			JRD	BPG	ANG	JRD
REV	DATE	REVISION DESCRIPTION				DES	CADD	CHK	RVW
PROJECT									
DOMINION POSSUM POINT POWER STATION PRINCE WILLIAM COUNTY, VIRGINIA									
TITLE									
WATER TREATMENT SYSTEM SITE PLAN (PRIMARY LOCATION)									
		PROJECT No.		16-62150		FILE No.		1662150B02A	
		DESIGN	JRD	12/01/16		SCALE		AS SHOWN	
		CADD	BPG	12/01/16					
		CHECK	ANG	12/01/16					
		REVIEW	JRD	12/01/16					
00022444									
DRAWING 2A									





DRAWING 2A

- NOTES:
1. DISCHARGE FROM POND A, B, C, AND E MAY BE SENT TO POND D OR TO INFLUENT STORAGE TANKS
 2. DISCHARGE FROM POND D MAY BE SENT TO INFLUENT STORAGE TANKS
 3. PIPING SHOWN FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY.



AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO ON 10/13/2016.
MAP DATA BY: GOOGLE, IMAGERY DATE: 04/14/2016

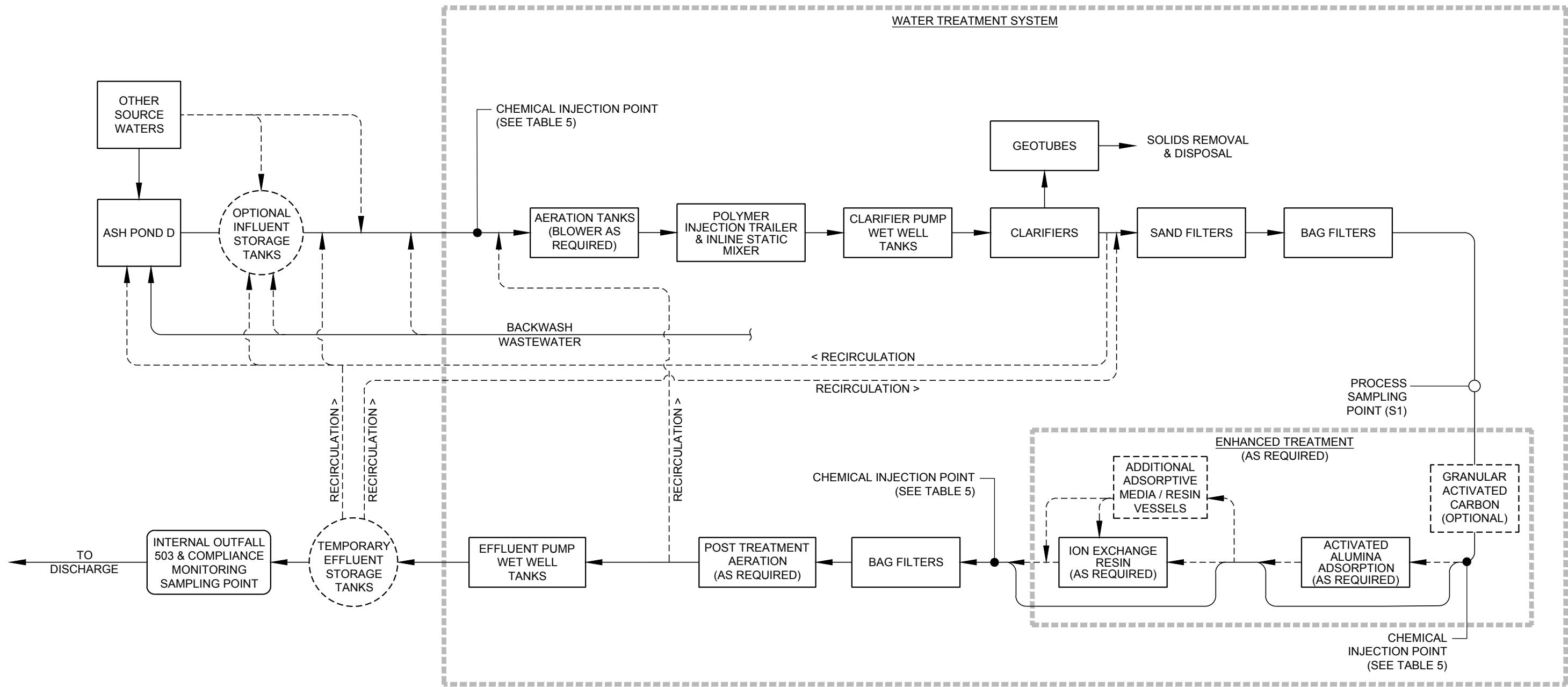


		12/14/16	RESPONSE TO DEQ COMMENTS			JRD	BPG	ANG	JRD
REV	DATE	REVISION DESCRIPTION				DES	CADD	CHK	RVW
PROJECT									
DOMINION POSSUM POINT POWER STATION PRINCE WILLIAM COUNTY, VIRGINIA									
TITLE									
WATER TREATMENT SYSTEM SITE PLAN (ALTERNATE LOCATION)									
		PROJECT No.		16-62150		FILE No.		1662150B02B	
		DESIGN	JRD	12/01/16		SCALE		AS SHOWN	
		CADD	BPG	12/01/16		DRAWING 2B			
		CHECK	ANG	12/01/16					
		REVIEW	JRD	12/01/16					



DRAWING 2B

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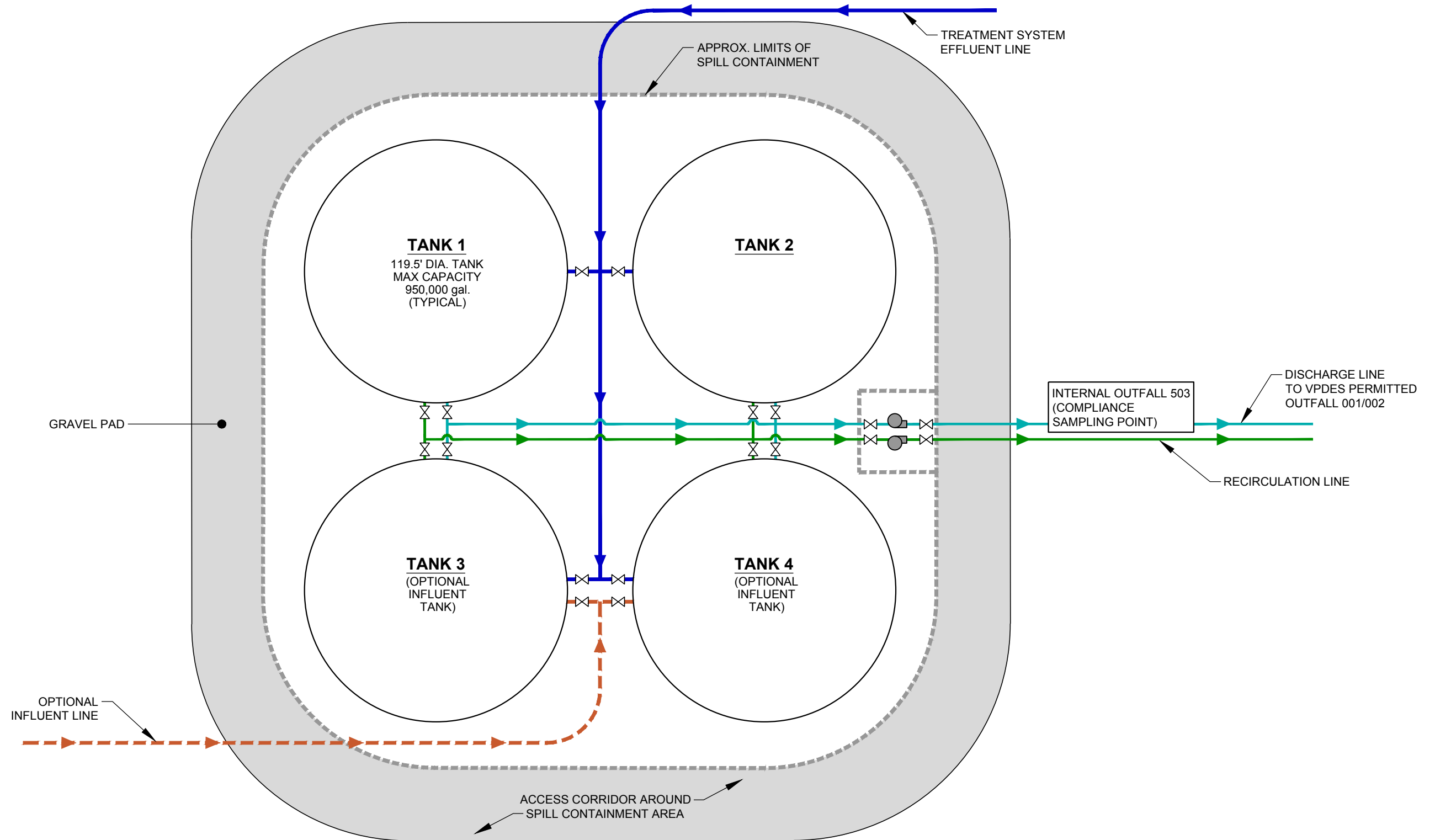
NOTES

1. TREATMENT SYSTEM CONFIGURATION AS OPERATED BY PROACT.
2. PUMP, CHEMICAL ADDITION AND POLYMER ADDITION LOCATIONS MAY BE MODIFIED AS NEEDED FOR pH ADJUSTMENT AND TREATMENT.
3. pH ADJUSTMENT WITH HYDROCHLORIC ACID OR CAUSTIC SODA IS TO BE APPLIED, AS REQUIRED.
4. BACKWASH WASTEWATER SOURCES MAY INCLUDE SAND FILTERS AND VESSELS USED FOR ENHANCED TREATMENT.

LEGEND

- FLOW PATH
- - - - -→ ALTERNATE FLOW PATH

	12/14/16	RESPONSE TO DEQ COMMENTS				JRD	BPG	ANG	JRD
	REV	DATE	REVISION DESCRIPTION				DES	CADD	CHK
PROJECT									
DOMINION POSSUM POINT POWER STATION PRINCE WILLIAM COUNTY, VIRGINIA									
TITLE									
PROCESS FLOW DIAGRAM									
	PROJECT No.		16-62150		FILE No.		1662150B03		
	DESIGN	JRD	12/01/16		SCALE		AS SHOWN		
	CADD	BPG	12/01/16		<div>DRAWING 3</div>				
	CHECK	ANG	12/01/16						
	REVIEW	JRD	12/01/16						





NOTES

1. PIPING SHOWN FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY.
2. SPACE BETWEEN TANKS TO BE GRADED TO DRAIN IN CONTAINMENT AREA.
3. PROCESS SAMPLES ARE TO BE TAKEN FROM TANKS.
4. OPTIONAL INFLUENT TANKS MAY BE SWITCHED.

LEGEND

- EFFLUENT LINE
- OPTIONAL INFLUENT LINE
- RECIRCULATION LINE
- DISCHARGE LINE TO INTERNAL OUTFALL 503 AND OUTFALL 001/002
- VALVE
- BOOSTER PUMP

	12/14/16	RESPONSE TO DEQ COMMENTS				JRD	BPG	ANG	JRD	
REV	DATE	REVISION DESCRIPTION				DES	CADD	CHK	RWW	
PROJECT										
DOMINION POSSUM POINT POWER STATION PRINCE WILLIAM COUNTY, VIRGINIA										
TITLE										
CONCEPTUAL OPTIONAL INFLUENT / EFFLUENT STORAGE TANK SCHEMATIC										
		PROJECT No.		16-62150	FILE No.		1662150B04			
		DESIGN	JRD	12/01/16	SCALE		AS SHOWN			
		CADD	BPG	12/01/16	000 222447					
		CHECK	ANG	12/01/16						
		REVIEW	JRD	12/01/16						
DRAWING 4										



DRAWING 4

APPENDICES

APPENDIX A
ORIGINAL TREATABILITY STUDY AND CONCEPTUAL TREATMENT SYSTEM DESIGN
BASIS



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March 3, 2016

Alan Eudy
Glover Construction
4462 US-301
Pleasant Hill, NC 27866
Phone: (252) 578-7134
Email: alan.eudy@gmail.com

RE: Treatability Study Dominion Dumfries VA

Mr. Eudy

Enclosed is an explanation of the theory behind our water treatment proposal along with the onsite treatability study that was conducted on the Dominion site in Dumfries, VA. Our recommendations of chemistry was based on design, effectiveness, and changing variables that we expect during the life of the project. We would like to take an opportunity to define existing chemistries proposed and tested during the site visit. Many commodity chemistries exist and while effective have limitations. We see many times during standardized bench testing chemistries used will succeed during analysis fail during deployment. ProAct/Carbonair uses an approach to closely replicate onsite conditions during our bench testing that factors in many aspects often overlooked by standardized testing. Finally, our goal is to find green or environmentally friendly chemistries that will give you and your client comfort that minimizes exposure to your team and the ecosphere.

Mitchell Stocki
Applications Sales Engineer
ProAct Services Corporation

Sawang Nottakun PhD
Senior Process Engineer
Carbonair Environmental Systems



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Description of Proposed Wastewater Treatment Process at the Old Dominion, Dumfries, VA Site

ProAct/Carbonair has proposed a system to treat wastewater at the Dominion, Dumfries, VA site based on the following information:

Maximum flow rate:	2,000	gpm
Average flow rate:	1,750	gpm
Total volume to be treated:	200,000,000	gallons
Water temperature:	55	°F

Contaminant	Influent Conc. ^(a)	Effluent Criteria ^(b) (Monthly Average)	Effluent Criteria ^(b) (Daily Maximum)	Unit
pH	7.85	6-9	6-9	s.u.
TSS	150	30	100	mg/L
O&G	6.9	15	20	mg/L
Aluminum (total)	17,800	NL	NL	ug/L
Aluminum (dissolved)	280	N/A	N/A	ug/L
Antimony (total)	14	1,300	1,300	ug/L
Antimony (dissolved)	16	1,300	1,300	ug/L
Arsenic (total)	1,200	240	440	ug/L
Arsenic (dissolved)	900	N/A	N/A	ug/L
Barium (total)	830	NL	NL	ug/L
Barium (dissolved)	380	N/A	N/A	ug/L



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Beryllium (total)	7.2	NL	NL	ug/L
Beryllium (dissolved)	0.18	N/A	N/A	ug/L
Boron (total)	1,300	NL	NL	ug/L
Boron (dissolved)	1,400	N/A	N/A	ug/L
Cadmium (total)	0.27	1.4	2.6	ug/L
Cadmium (dissolved)	< 1	N/A	N/A	ug/L
Chloride	251,000	370,000	670,00	ug/L
Chromium III (total)	16	88	160	ug/L
Chromium III (dissolved)	2.6	N/A	N/A	ug/L
Chromium VI (total)	0.14	17	32	ug/L
Chromium VI (dissolved)	0.12	N/A	N/A	ug/L
Cobalt (total)	16	NL	NL	ug/L
Cobalt (dissolved)	2.2	NL	NL	ug/L
Copper (total)	84	9.6	18	ug/L
Copper (dissolved)	1.9	N/A	N/A	ug/L
Iron (total)	11,800	NL	NL	ug/L
Iron (dissolved)	7,100	N/A	N/A	ug/L
Lead (total)	38	14	26	ug/L
Lead (dissolved)	< 2	N/A	N/A	ug/L
Mercury (total)	< 0.2	1.2	2.2	ug/L
Mercury (dissolved)	0.35	N/A	N/A	ug/L
Molybdenum (total)	430	NL	NL	ug/L
Molybdenum (dissolved)	430	N/A	N/A	ug/L
Nickel (total)	28	24	44	ug/L
Nickel (dissolved)	8	N/A	N/A	ug/L
Selenium (total)	40	8	15	ug/L
Selenium (dissolved)	25	N/A	N/A	ug/L
Silver (total)	< 1	2.2	4.0	ug/L

Silver (dissolved)	< 2	N/A	N/A	ug/L
Thallium (total)	1.4	0.94	0.94	ug/L
Thallium (dissolved)	0.65	N/A	N/A	ug/L
Vanadium (total)	7.2	NL	NL	ug/L
Vanadium (dissolved)	< 2	N/A	N/A	ug/L
Zinc (total)	66	98	180	ug/L
Zinc (dissolved)	190	N/A	N/A	ug/L

- a) **The design influent concentrations are based on the maximum detected concentrations from Pond D and Pond E.**
b) **The effluent criteria are based on the VDEQ limits for discharge via Outfall 503 to Outfall 001.**
Bold values indicate the exceedance of the discharge limits.

NL = No limit

N/A = Not applicable

As can be seen from the table shown above, there are only five contaminants (arsenic, lead, nickel, selenium, and thallium) that appeared to have TOTAL concentration levels exceeding the VDEQ discharge limits. Of these five contaminants, there are only two contaminants (arsenic and selenium) that appeared to have DISSOLVED concentration levels exceeding the VDEQ discharge limits.

The wastewater from the ponds will be first pumped into multiple frac tanks arranged in parallel where gross solids will be allowed to settle. Each frac tank will be installed with a blower which can be used to aerate the wastewater in order to oxidize and convert arsenic that may be in the form of arsenite (As+3) into the form of arsenate (As+5) which can be more effectively removed by iron salt co-precipitation and activated alumina (AA) adsorption. However, we believe that arsenic in the ponds may have already been slowly oxidized by ambient air for quite some time, and the aeration may be unnecessary.

The effluent from the frac tanks will be injected with a cationic and anionic polymeric flocculation aiding agents, and delivered to multiple Geotubes arranged in parallel, where flocs will be allowed to form and settle. The main purpose of this step is to reduce the high arsenic concentration to such a level that the polishing AA media provided downstream can last a reasonably long period of time. Selenium and other heavy metals (lead, nickel, thallium) are also expected to be removed in this step. From an onsite treatability study conducted at the Dominion site, BHR-P50 (hybrid PAC biopolymer blend) in conjunction with LBP-2101 (anionic polysaccharide) were found to be very effective in flocculation and removal of suspended solids in this wastewater.

The filtrate from the Geotubes will be delivered to multiple self-backwashable sand filters followed by small micron bag filters to remove fine particulates that may be associated with insoluble heavy metals. After the flocculation and particulate filtration steps, the wastewater is expected to be relatively clear and should only contain dissolved metals. The clear wastewater will be further treated using AA and a weak acidic cationic exchange resin. The AA will be used to remove residual dissolved arsenic, selenium, and thallium while the resin will be used to remove residual dissolved cationic heavy



metals (Al, Ba, Cr(III), Cu, Fe (II), Pb, Ni, Tl, and Zn). Although all the dissolved cationic metals are expected to be below the discharge limits, the resin is recommended as a precautionary measure. The resin will not be placed on line unless some of those cationic metals are found to exceed the discharge limits.

On-site Treatability Study at the Dominion, Dumfries, VA Site

Introduction

The initial testing conducted onsite encompassed the homogenization of the downstream ash pond with the upstream discharge pond currently undergoing a dredge process. Although an exact replication of the water was not possible we looked at various concentrations during the homogenization process. TSS solids from the ash pond had NTU values over 2000 while NTU values from the upstream pond had under 20. The initial analysis took into account the discussion of the treatment train, flow rate, and effluent limitation guideline. For the purposes of this onsite test Particulate size analysis, NTU, pH, Conductivity, TDS, Salinity, and arsenic was measured only. Basic dose response testing was conducted using various chemicals as listed below:

Aluminum Sulfate 48%

Anionic PAM

Cationic PAM

Chitosan

Anionic Biopolymer Chitosan mix.

Dry anionic PAM mineral blend.

Hybrid inorganic biopolymer blend.

The homogenized particulate size analysis indicated that over 65% of the solids were under 1.5 μm . This analysis gave us the starting point to begin the process of chemical selection. Commodity chemicals such as Alum or other inorganic salts are effective in neutralizing the pronounced –ve charge “Zeta Potential” that encompasses the colloidal particulate allowing for collision, aggregation and precipitation under Van der Waals equation. While effective in supernates that have little velocity these have no sheer resistance abilities and often must be followed by a high molecular weight polymer such as PAM or polyacrylamides.

Anionic and Cationic polyacrylamides are derived from petroleum which gives the precipitates a gelatinous floc structure which is often extremely viscous and stick by nature leading to blinding of any filtrate material weather fabric, sand, or remediation media. Due to the fact that both geobag and sand are proposed in the model both forms of PAM were dismissed.

Anionic Biopolymers were tested both pre & post Alum however because of the solids content the amount of Alum required depressed the alkalinity to levels that compromised the pH. Additionally the resulting amount of un-biodegradable aluminum ion that would be present within the sludge was found



to be high and additional costs in handling may be high. Buffering the pH could be accomplished but did not seem desirable to the team onsite.

Importantly as rapid clarification and precipitation was during the study floc characteristics were as equally important. In most cases bench testing will use a set standard by mixing at fast and slow rates proceeded by observing the sample at 0 velocity. While effective in determining clarification this doesn't replicate real time events and often the agglomerated flocs sheer apart by-passing filtration measures. Our sampling procedures measures clarification, sedimentation precipitation velocity all while maintaining energy within the container. Finally the precipitate is filtered under pressure rather than gravity to ensure sheer resistance abilities.

Treatability

After the initial dose range finding studies were concluded we focused on two chemistries that gave us the indication for success and cohabitation effectiveness within the discussed treatment train.

BHR-P50 optimized at 100 mg/L. is a hybrid PAC biopolymer blend. The constituents of this chemistry provides the inorganic metal salt that reverses the zeta potential like alum but with 50% less alumni content resulting in little to no pH or alkalinity fluctuations. The biopolymer constituent allows for a more pronounced aggregation and provided the precipitate moderate sheer ability. This blend is classified as a cationic coagulant/polymer.

LBP-2101 optimized post BHR-P50 at 50 mg/L. is an anionic polysaccharide. It's constituent which differs from PAM's form an excellent floc when used in conjunction with a cationic coagulant or polymer. Once agglomerated the floc has excellent sheer abilities suitable for high flow filtration. Due to the fact it is compromised from simple sugar monomers these have effective filtration abilities with no blinding effects. The additional benefit of using these two chemistries in conjunction leave no possible +ve charge entering the surface waters and in fact residual testing can be accomplished onsite. Chemistries using cationic constituents have a much higher Eco toxicity then anionic constituents. This combination leaves with a net neutral charge. +/- The proposed chemical model reduced the overall NTU value by 97% with settling alone, filtration combination noted a 99% reduction in NTU's.

The above concentrations allows for flexibility in changing conditions. Our operators will have the capability to monitor and adjust if necessary in real time rather than waiting for outside or offsite lab analysis. No change in pH or other water characteristics were noted. Arsenic was not present in any of the samples collected. Both chemistries are listed as non-hazardous.



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Customer: Glover Construction
Site: Dumfries, VA
Date: 1/19/16

Design Basis: Flow rate: **2,000** gpm (maximum)
1,750 gpm (average)
Volume to be treated: 200,000,000 gallons
Water temperature: 55 °F (assumed)

Contaminant	Influent Conc. ^(a)	Effluent Criteria ^(b) (Monthly Average)	Effluent Criteria ^(b) (Daily Maximum)	Unit
pH	7.85	6-9	6-9	s.u.
TSS	150	30	100	mg/L
O&G	6.9	15	20	mg/L
Aluminum (total)	17,800	NL	NL	ug/L
Aluminum (dissolved)	280	N/A	N/A	ug/L
Antimony (total)	14	1,300	1,300	ug/L
Antimony (dissolved)	16	1,300	1,300	ug/L
Arsenic (total)	1,200	240	440	ug/L
Arsenic (dissolved)	900	N/A	N/A	ug/L
Barium (total)	830	NL	NL	ug/L
Barium (dissolved)	380	N/A	N/A	ug/L
Beryllium (total)	7.2	NL	NL	ug/L
Beryllium (dissolved)	0.18	N/A	N/A	ug/L
Boron (total)	1,300	NL	NL	ug/L
Boron (dissolved)	1,400	N/A	N/A	ug/L
Cadmium (total)	0.27	1.4	2.6	ug/L
Cadmium (dissolved)	< 1	N/A	N/A	ug/L
Chloride	251,000	370,000	670,00	ug/L
Chromium III (total)	16	88	160	ug/L
Chromium III (dissolved)	2.6	N/A	N/A	ug/L
Chromium VI (total)	0.14	17	32	ug/L
Chromium VI (dissolved)	0.12	N/A	N/A	ug/L
Cobalt (total)	16	NL	NL	ug/L
Cobalt (dissolved)	2.2	NL	NL	ug/L
Copper (total)	84	9.6	18	ug/L
Copper (dissolved)	1.9	N/A	N/A	ug/L
Iron (total)	11,800	NL	NL	ug/L
Iron (dissolved)	7,100	N/A	N/A	ug/L
Lead (total)	38	14	26	ug/L
Lead (dissolved)	< 2	N/A	N/A	ug/L
Mercury (total)	< 0.2	1.2	2.2	ug/L
Mercury (dissolved)	0.35	N/A	N/A	ug/L
Molybdenum (total)	430	NL	NL	ug/L

00022456

Molybdenum (dissolved)	430	N/A	N/A	ug/L
Nickel (total)	28	24	44	ug/L
Nickel (dissolved)	8	N/A	N/A	ug/L
Selenium (total)	40	8	15	ug/L
Selenium (dissolved)	25	N/A	N/A	ug/L
Silver (total)	< 1	2.2	4.0	ug/L
Silver (dissolved)	< 2	N/A	N/A	ug/L
Thallium (total)	1.4	0.94	0.94	ug/L
Thallium (dissolved)	0.65	N/A	N/A	ug/L
Vanadium (total)	7.2	NL	NL	ug/L
Vanadium (dissolved)	< 2	N/A	N/A	ug/L
Zinc (total)	66	98	180	ug/L
Zinc (dissolved)	190	N/A	N/A	ug/L

- a) Based on the maximum detected concentrations from Pond D and Pond E.
b) Based on the VDEQ limits for discharge via Outfall 503 to Outfall 001.
Bold values indicate the exceedance of the discharge limits.
NL = No limit
N/A = Not applicable

Recommendations:

Aeration Tanks (to oxidize arsenic) Carbonair does not believe this step is necessary
4 – 21,000 gallon tank

Injection Trailers

- Includes automatic injection capabilities for pH Adjustment, Flocculation and FeCl_3

Ferric Chloride (FeCl_3) Injection (to produce iron flocs for adsorption of arsenic)

10-gph injection pump

- We recommend that FeCl_3 be initially injected at a dosage of 10 ppm. The required injection rates of the 20% by wt solution are calculated to be 4.2 and 3.7 gph at 2,000 and 1,750 gpm, respectively.
- The initial 40% FeCl_3 solution consumption rates are calculate to be ~ 50 and 44 gpd at 2,000 and 1,750 gpm, respectively.

PolymerInjection (to enlarge iron flocs for adsorption of arsenic)

10-gph injection pump

- Exact polymer and dosing to be determined by bench testing

Flocculation/Settling Tanks/Basins (to allow iron to form flocs to adsorb arsenic)

Sand Filters (to remove suspended iron flocs)

Four Model 4-54 sand filters in parallel, each Model 4-54 comprising four 54-inch diameter filters in parallel

- Each filter in Model 4-54 will be backwashed with treated water from the other three filters for at a backwashing flow rate of ~ 250 gpm for 10 minutes. During the backwashing period, the total flow rate through the four Model 4-54's should be reduced to ~ 1,500 gpm.
- We recommend that the backwash water be delivered back to the ponds.

Post-Filters (to remove fine particulates)

Four Krystil Klear Multi-Round Model 3636 bag filter housings (1-micron high efficiency) in parallel

- The post-filters are recommended for the removal of fine particulates, which may be associated with any heavy metals.

Activated Alumina Adsorbers (to remove dissolved selenium)

Four PC78's in parallel, each vessel filled with 500 ft³ (20,000 lbs) of granular activated alumina (AA)

- Assuming all the dissolved arsenic to be removed by pre-treatment upstream , all the four vessels are predicted to last ~ 598.4 million gallons of water or **208** days of continuous operation at 2,000 gpm.

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ARSENIC REMOVAL SYSTEM

Carbonair

1480 County Road C West, Roseville, MN 55113

Phone: 800-526-4999 Fax: 651-202-2985 www.carbonair.com

Project name:	Dumfries, VA	
Flow rate:	2000	gpm
Total selenium (as arsenic) concentration:	25	ppb
Arsenite (AsIII) concentration:	Unknown	ppb
Arsenate (AsV) concentration:	Unknown	ppb

Adsorber model:	PC78	
Number of adsorbers:	4	
Adsorber arrangement:	In parallel	
Type of adsorbing media:	Activated Alumina	
Media bulk density:	40	lbs/cu.ft.
Volume of media in each adsorber:	500	cu.ft.
Total volume of media:	2000	cu.ft.
Total mass of media:	80000	lbs
Preoxidation:	Yes	

Estimated treatable volume of water (with preoxidation):	598,400,000	gal
--	-------------	-----

A

B

C

D

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F

ITEM	QTY	DESCRIPTION	MANUFACTURER	MANF NO
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1

1

2

2

3

3

4

4

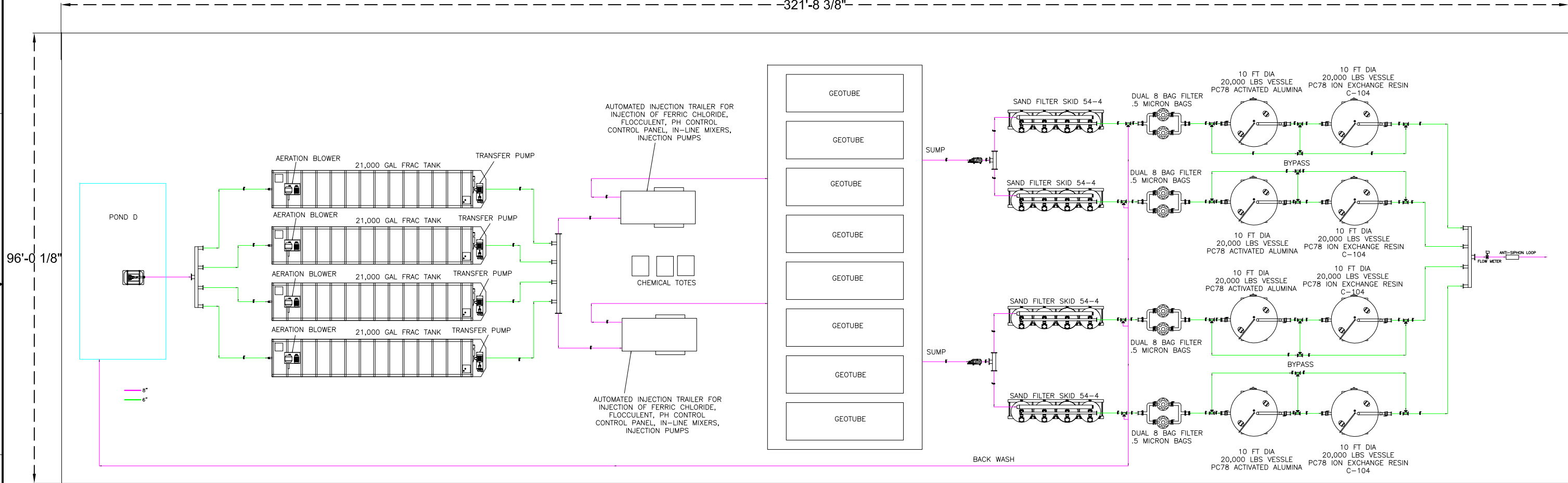
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5

6

6

-321'-8 3/8"-



REV	DATE	DESCRIPTION	DRW	APPR
-----	------	-------------	-----	------

DRAWING NO. 1

CUSTOMER

DRAWN BY JONATHAN DIPPLE

SIZE B

MATERIAL

DATE 2/1/16

SHEET 1

SCALE NTS

REV

JOB NO.

UNIT NO.



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PLAN VIEW
2000 GPM WTS

00022460

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APPENDIX B
TREATABILITY STUDY: ADDITIONAL TREATMENT STEPS



Dominion Power, Dumfries Ash Pond: Additional Treatment Steps J11000

Innovative Air & Water Treatment Solutions



Prepared for:	Alan Eudy Glover Construction 4462 US-301 Pleasant Hill, NC 27866	
Prepared by:	Sawang Notthakun, Ph.D. Stephen Smiddy Claire Peavey ProAct Services Corporation 1140 Conrad Industrial Drive Ludington, MI 49431	Process Engineer Project Engineer Field Engineer

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Executive Summary

ProAct Services, a contractor for Glover Construction Company, established a water treatment system intended to treat streams generated from dewatering activities conducted by Dominion in Dumfries, Virginia. This report addresses current challenges found in the treatment system, especially found from effluent concentrations of selenium. Depending on influent constituents, potential solutions to introduce involve chemical, physical, and media enhancements to the existing treatment system. These treatment options are also analyzed according to their feasibility of further decreasing contaminants levels in the system.

The option that poses the highest likelihood of decreasing effluent selenium is largely centered around chemical and physical treatment alterations. To do so, an increase in injection rate of both ferric chloride and sodium sulfite is required. To achieve this, the addition of plate clarifiers to the process will create conditions most conducive to selenate reduction and removal. In place of LBP-2101 and P50, introduction of anionic polyacrylamide emulsion (PAM) at the chemical injection trailers may be utilized to create stronger flocs. In addition, the introduction of deep-bed sand filters will provide an additional safeguard to prolong life of media vessels. Downstream in the system, post-treatment aeration tanks or Venturi tubes will be used should toxicity become a concern.

In addition to physical and chemical treatment, additional media vessels may be utilized downstream of the Activated Alumina. In order of increasing polishing capability, depending on influent constituents media such as AM, A100 Ion Exchange, anion-pretreated ion-exchange medias or granular activated carbon may be effective for further reduction of selenium concentrations. Depending on influent constituents, the information presented herein shows each of these technologies has potential to decrease contaminant levels below desired discharge levels.

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1. Background

Glover Construction Company contracted ProAct Services to treat water from dewatering activities conducted by Dominion in Dumfries, Virginia. This report addresses current challenges found in the treatment system before introducing solutions likely to enhance the treatment system currently on-site. An overview of treatment results reported by off-site labs over the month of September is shown in Table below.

Table 1. Summary of effluent values from treatment system, September 2016.

Date	Time	Selenium Concentration (ppb)
5/6/2016	11:46	2.7
5/9/2016	11:40	<2.5
5/10/2016	8:35	<2.5
5/10/2016	13:40	2.6
5/16/2016	6:00	2.6
5/16/2016	6:10	5.9
6/11/2016	8:07	<2.5
6/12/2016	11:10	<2.5
6/13/2016	11:36	<2.5
6/14/2016	9:17	3.9
6/20/2016	8:00	7.77
7/11/2016	14:36	7.51
7/28/2016	13:18	5.75
8/9/2016	13:15	5.7
8/15/2016	14:00	5.71
8/22/2016	9:45	4.65
9/14/2016	10:40	6.79
9/15/2016	12:00	7.42
9/20/2016	0:00	1.44

While existing treatment options utilized by ProAct are able to treat many of the contaminants initially present in influent water, varying influent constituents require additional treatment steps to further decrease selenium levels. An analysis of each treatment option can be found as follows:

2. Chemical and Physical Additions

2.1 Increase in Reducing Agent

Many selenium-containing compounds exist in nature. In order to determine the most effective treatment options, first an analysis of speciation of selenium was performed by GAI.

Table 2. Speciation of selenium found in the ash ponds at Possum Point.

Form of Selenium	Concentration (ppb)	Percentage (%)
Selenate	4.45	70.0
Selenite	1.16	15.9
Particulates	1.69	23.1
Total	5.8	100

Although the total selenium concentration may vary with sampling location, the overall trend in profile stays consistent. As shown in Table 2, the majority of selenium is present in solution as selenate – the form of which cannot be very effectively treated by ferric chloride flocculation and activated alumina (AA) adsorption. A further analysis of speciation of selenium-containing compounds can be found in Appendix A, as a series of bench-scale tests were conducted in October of 2016 in order to propose initial treatment recommendations for the system. The bench-scale test showed that ferric chloride and sodium sulfite dosages at 50 and 66 ppmv (by volume), respectively, had no effect on the enhanced removal of selenium. The pH and ORP were measured to be 8.8 s.u. and 88 mV prior to AA adsorption. This sulfite dosage is not sufficient to lower the ORP to a level where selenate can be converted in to selenite.

As presented in Table 3, a more recent bench-scale test was performed on influent water to the treatment train, showing the effect of higher sodium sulfite dosages on the ORP. This information will be used to determine initial chemical injection rates and is expected to show where selenate can be converted to selenite.

Table 3. Bench-scale Na₂SO₃ dosing results, October 25, 2016.

Sodium Sulfite (ppm)	pH	ORP (mV)
0	8.2	64
600	8.7	30
3000	9.5	-70

Table 4 shows results from pilot-scale system operation at Dominion's Chesterfield Integrated Ash Project (CHIAP). The pilot-scale system included ferric chloride and sodium sulfite injection, caustic and polymer injection, plate clarifiers, sand and bag filtration, along with adsorbent and ion exchange media. The results show that this treatment system successfully reduced the influent selenium concentrations of 28-45 ppb down to below 8 ppb with an average effluent concentration of 2.7 ppb. This was achieved with sulfite dosages of 200-1,000 ppmv (by volume),

which are higher than the dosages that have been used at the Dumfries site. Only one testing event on 10/4/16 with Lazy River Surface as the wastewater source shows that selenium was removed to 2.54 ppb without the use of sodium sulfite. It is believed that selenium at this location was already in the form of selenite.

Table 4. Selenium Removal by Pilot-Scale System at the Chesterfield Site

Date	Wastewater Source	Ferric Chloride (ppmv)	Caustic Soda (ppmv)	Sodium Sulfite (ppmv)	Influent Selenium (ppb)	Effluent Selenium (ppb)
9/16/16	Main Surface	Filtration Only	Filtration Only	Filtration Only	34.9	32.1
9/19/16	Main Surface	83	19	667	34.9	7.75
9/20/16	Main Surface	83	25	667	45.2	4.93
9/21/16	Main Surface	82	28	209	45.2	2.51
9/22/16	Main Surface	157	0	1,000	45.2	2.19
9/23/16	Main Surface	53	0	453	45.2	2.01
9/28/16	Main 5 ft.	82	25	657	35.5	1.54
9/29/16	Main 5 ft	84	25	671	28.1	-
10/3/16	Lazy River Surface	83	25	667	33.1	2.21
10/4/16	Lazy River Surface	83	25	0	27.9	2.54
10/4/16	Lazy River Bottom	83	25	667	28.3	3.27
Average					33.3	2.7

This data shows increased injection of sodium sulfite at the existing pre-aeration tank location at the Dumfries site has potential for an increase in selenium removal.

The removal can be further enhanced by injecting sodium sulfite immediately prior to activated alumina adsorption. This will be performed to ensure ORP is at a low enough level to convert selenate to selenite, which can be captured by Activated Alumina.

When compared with other reducing agents, sodium sulfite is the least expensive and most user-friendly and environment-friendly chemical. However, depending on influent conditions, other

strong reducing agents may be required should sodium sulfite not sufficiently lower the ORP. In lieu of Sodium Sulfite, other reducing agents such as sodium bisulfite, sodium thiosulfate, calcium thiosulfate, ascorbic acid, sodium ascorbate, or ferrous hydroxide may be substituted. Utilization of these strong reducing agents is a common practice in industry, as the process of injecting various reducing agents has consistent reliability in their ability to reduce contamination levels throughout wastewater treatment systems (Bowers & Eckenfelder, 2003).

As Se^{6+} is reduced to Se^{4+} , potential also exists for the system to begin reacting with dissolved oxygen (DO) present in water, a process which can pose toxicity issues to aquatic life. For this reason, addition of post-treatment aeration tanks or venturi tubes may be required in case the effluent ORP falls into the negative range.

2.2 Plate Clarifiers

While an increase in sodium sulfite concentrations has the potential to convert selenate to selenite, positive results may also be achieved by an increase in ferric chloride injection rates. According to the EPA Office of Water, a high dose of ferric chloride will improve removal of iron and contaminants from the system, by iron-coprecipitation. As a result of increased ferric chloride injection, a larger volume of iron hydroxide sludge will be produced and built up in the system. Therefore, in order to optimize the removal of buildup of iron-based hydroxides, addition of plate clarifiers with periodic sludge withdrawal will be put into place. Plate clarifiers were developed to improve the efficiency of settling tanks by utilizing multiple parallel plates to increase the settling surface area and shorten the settling distance.

When compared to commonly used solids removal options, such as geotubes, plate clarifiers have been found to have significantly higher removal efficiencies (Cheremisinoff, 2002). Removal of selenium through chemical injection followed by a plate clarifier was proven to be very effective when working with contaminants at the Chesterfield site. Table 5 shows results from pilot-scale system operation at the Chesterfield site comparing selenium removal using a plate clarifier versus a geotube tank. Of all the five testing events, the plate clarifier after ferric chloride flocculation was found to reduce selenium concentration levels to well below 8 ppb prior to polishing steps using adsorbent or ion exchange media. Of the two testing events, the geotube tank did not remove selenium to below 10 ppb.

Table 5. Selenium Removal by Plate Clarifier vs Geotube Tank at the Chesterfield Site

Date	Wastewater Source	Ferric Chloride (ppmv)	Caustic Soda (ppmv)	Sodium Sulfite (ppmv)	Influent Selenium (ppb)	Effluent Selenium From Plate Clarifier (ppb)	Effluent Selenium From Geotube Tank (ppb)
9/28/16	Main 5 ft	82	25	657	35.5	4.43	Not Tested
9/29/16	Main 5 ft	84	25	671	28.1	6.82	11.0
10/3/16	Lazy River Surface	83	25	667	33.1	4.33	10.6
10/4/16	Lazy River Surface	83	25	0	27.9	4.94	Not Tested
10/4/16	Lazy River Bottom	83	25	667	28.3	6.5	Not Tested

2.3 Polyacrylamides

Depending on influent constituents and their response to chemical injection, should LBP-2101 and P50 not create a strong enough floc, the addition of anionic polyacrylamide emulsion (PAM) may be utilized. PAM would be injected at the chemical injection trailer in lieu of LBP-2101 and P-50. These synthetic polymers are intended to bind solids together in water, thereby decreasing residual turbidity while inducing larger flocs than that produced by existing chemicals present in the treatment train (Product Evaluation, 2009). Data gathered during water treatment operation shows that influent turbidity values have been consistently low. Despite this, polyacrylamides have been proven to bind together particles and further reduce turbidity (Polymer Flocculation, 2016). The product specification and MSDS sheets will be provided when available.

2.4 Deep Bed Sand Filtration

As shown previously in Table 2, as much as 23% of selenium in the water at the Dumfries site is present in the form of particulates. With ferric chloride flocculation, however, a large fraction of selenium can be bound to iron flocs. Large flocs can be removed by means of a clarifier while small flocs can be removed by sand filters. In order to enhance selenium removal, a deep-bed sand filtration with a bed depth of at least 3 ft is recommended to prevent fine selenium-bound flocs from being carried over through the treatment system. A sand bed depth range of 3-6 ft for

deep bed sand filters to produce high effluent quality are given in MetCalf and Eddy (1991) (Appendix B).

Channeling is likely to occur in sand filters with shorter bed depths which are not deep enough to account for entrance and exit effects. While short-bed sand filters are applicable to most applications, deep bed sand filters are more appropriate to produce high effluent water quality at the Dumfries site. Frequent filter bag change-outs previously experienced during the operation at the Dumfries site indicate the ineffectiveness of the existing short-bed sand filters.

Appendix A details bench-scale tests done to assess the impact of sand filter addition, a summary of which can be found in Table 6. As can be seen from this table, the addition of ferric chloride and reducing agent increase turbidity levels. Addition of a set of deep bed sand filters was found to decrease the majority of turbidity.

Table 6. Impacts of treatment steps on pH and turbidity readings.

Sample	pH (s.u.)	Turbidity (NTU)
Influent	8.5	10.4
FeCl ₃ & Na ₂ SO ₃	6.6	24.8
Deep Bed Sand	7.0	1.26
Additional Na ₂ SO ₃	7.2	1.26
AA	8.8	1.36
A100	8.5	1.09

3. Tailored Media Adsorption

While existing media vessels on site are able to treat and remove selective contaminants from wastewater streams, addition of AM, A100 ion exchange media, anion-pretreated exchange medias or granular activated carbon may be required. Depending on influent constituents, each media contains the ability to further polish contaminants. The flexibility offered by lead/lag or parallel setup of media vessels allows for configuration to be adjusted based on varying influent conditions. This, when coupled with Proact's ability to offer both normal and enhanced treatment, offers maximum utilization of each polishing step.

3.1 ASG AM Adsorption Media

ASG AM Adsorption media is derived from activated alumina and complexed with manganese. As show in Figure 2, an initial bench-scale test using DI water provided a promising breakthrough curve. In an environment with the absence of other competing anions, this media is able to withstand a substantial number of bed volumes.

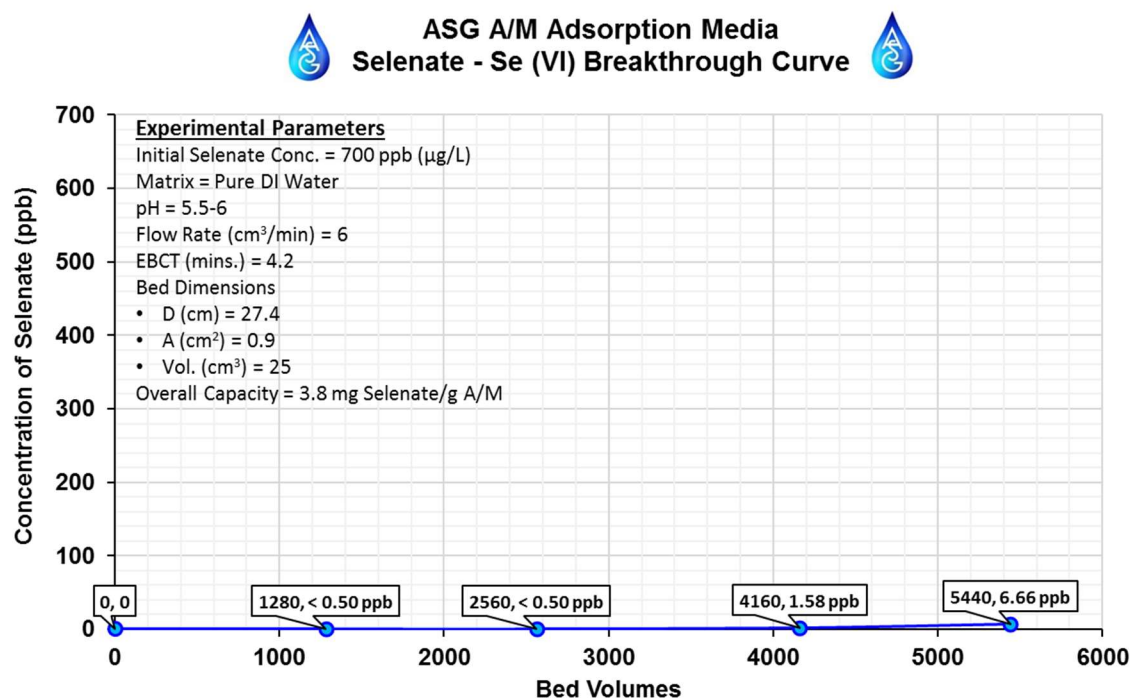


Figure 2. Breakthrough curve for manganese-complexed adsorption media.

A recent on-site pilot test on treatment of wastewater at the Dumfries site using 3.3 ft³ of AA followed by 2.0 ft³ of ASG shows that selenium was removed by AA alone down to below 8 ppb within the treated water volume of 1,200 BV at pH's of 6.5-7.2 s.u. and ORP's of < 90 mV. It is expected to be beneficial to maintain the pH and ORP in these ranges in the full-scale operation. Selenium was initially removed by ASG to a non-detectable level, however, the effluent concentration rapidly rose to reach the post AA levels after approximately 3,000 gallons of water or 100 BV treated, as shown in Figures 3(a) and 3(b) below, respectively. The early breakthrough is theorized to be attributed to the presence of other competing anions, mainly sulfate. Therefore, in the absence of competing ions, this media is a good option. Additional details regarding the pilot test can be found in Appendix D.

Figure 3(a) Selenium Removal

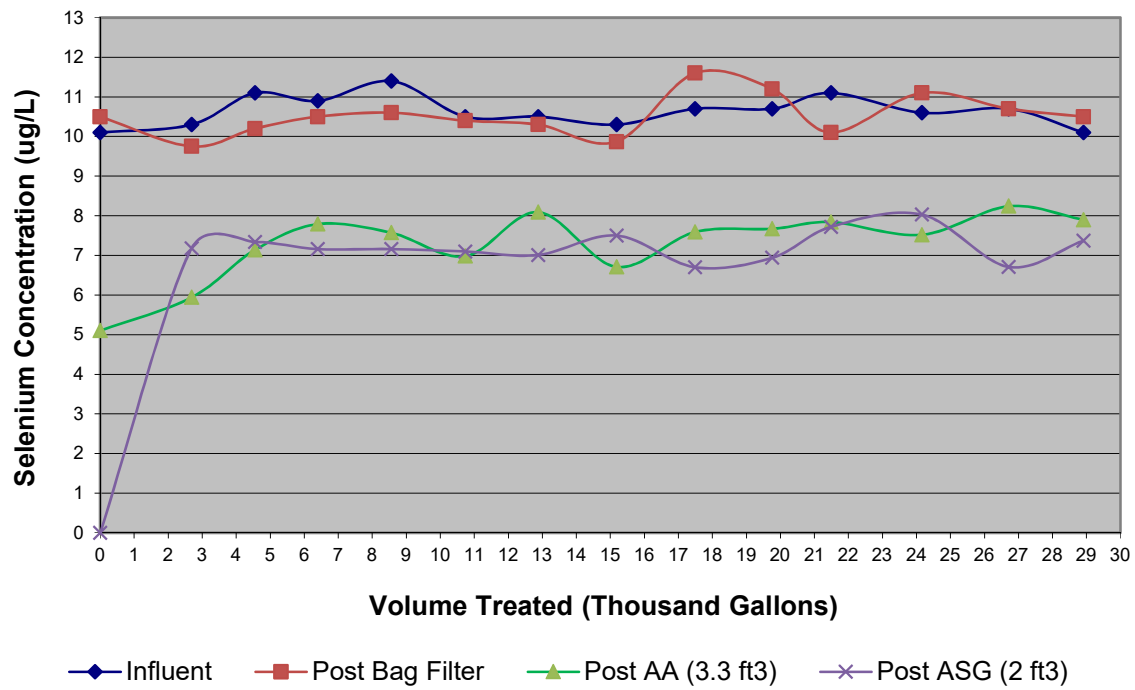
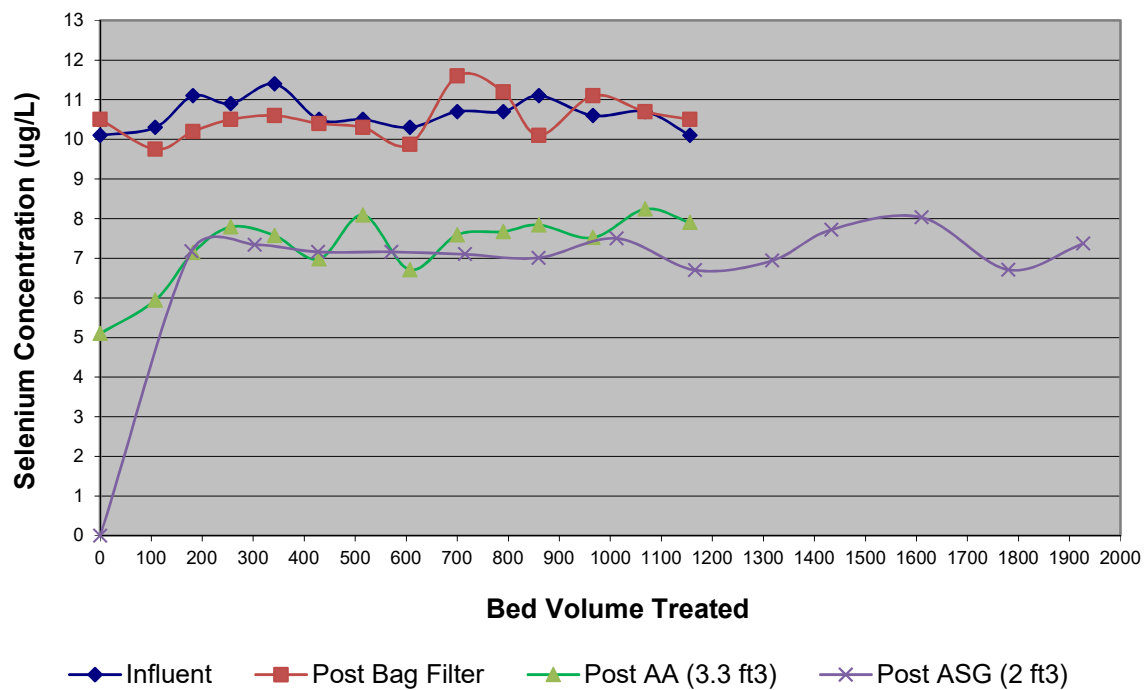


Figure 3(b) Selenium Removal



3.2 A100 Ion Exchange

A recent on-site pilot test on treatment of wastewater at the Dumfries site using 3.3 ft³ of activated alumina (AA) followed by 3.3 ft³ of A100 weakly basic anion exchange resin showed that A100 was able to remove selenium to below the selenium discharge limit of 8 ppb. Additional details regarding the pilot test can be found in Appendix C.

Figure 1 shows selenium plotted as a function of bed volumes (BV) treated. No selenium was removed by the 0.5 µm (nominal) bag filter. This implies that all the selenium in the Dumfries site wastewater is either dissolved or smaller than the nominal 0.5 µm bag filter pore size.

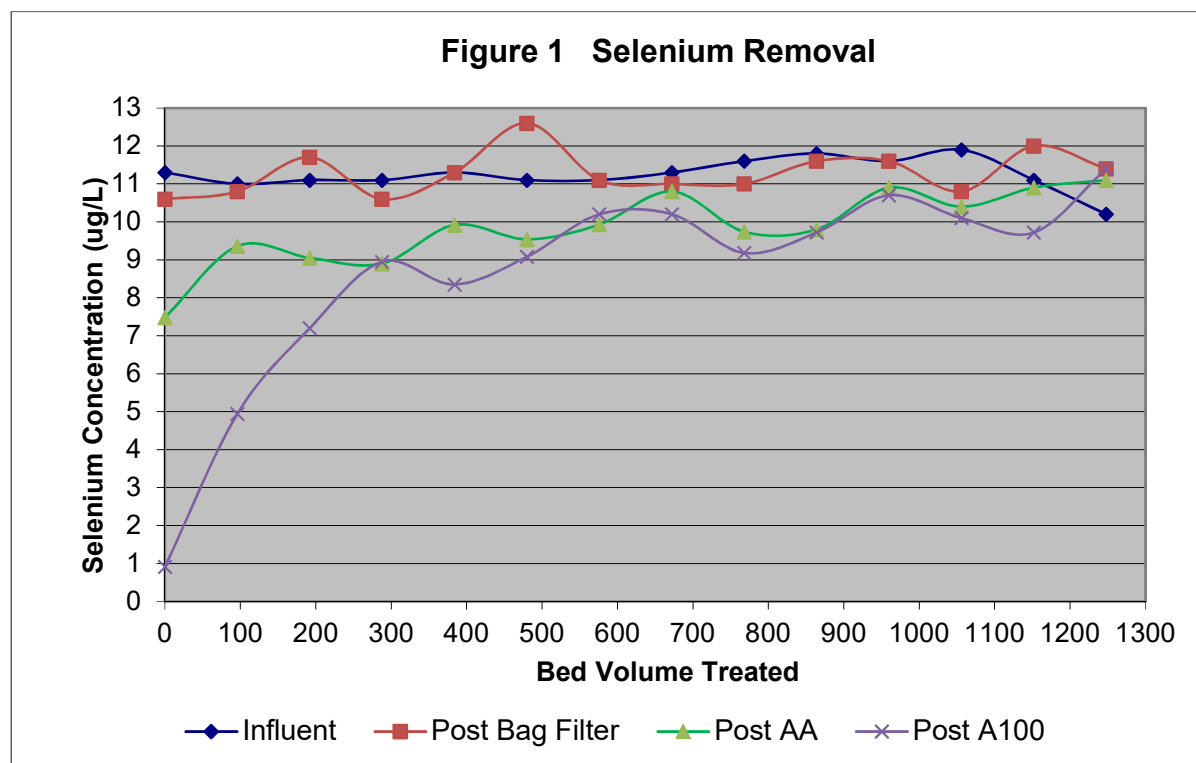


Figure 1 also shows that approximately 1-2 ppb of selenium was removed by AA. This portion of selenium is considered to be in the form of selenite which is most readily adsorbed by AA.

Initially, selenium was removed by A100 to below the discharge limit of 8 ppb. However, after approximately 250 BV treated, the selenium concentration rapidly rose to the discharge limitation level and reached the post AA levels after approximately 300 BV.

Based on these pilot test results, a full-scale system with two PC78 (10-ft diameter) vessels each containing 600 ft³ of resin would have to be changed every 14 hours. Early breakthrough is typically attributed to the presence of many other competing ions such as sulfate, nitrate, nitrite, and phosphate. For this particular project, anion analysis of wastewater at the Dumfries site showed that no nitrate, nitrite, and phosphate were found to be present while sulfate and

chloride were found to be present at 81 and 71 mg/L, respectively. Chloride has no effect on the selenium removal by A100 since the resin is already in the chloride form.

As the data suggests, the A100 service life can be prolonged by removing those competing anions, in this case mainly sulfate, prior to ion exchange. Sulfate can be precipitated as calcium sulfate or barium sulfate using lime (calcium hydroxide), barium chloride or barium carbonate. According to IUPAC-NIST's Solubility Database the solubilities of calcium sulfate and barium sulfate in water are of a sufficiently low magnitude, which suggests that precipitate will readily form. Should influent conditions impact the performance of this media, chemical injection will be required at the existing pre-aeration tank location.

3.3 Anion-Pretreated Ion Exchange Medias

In addition to media described above, two proprietary custom-created anions-pretreated media types have been produced. These media types have been developed specifically for ProAct's onsite treatment train at the Possum Point power station in order to selectively remove selenate. Zeolite and resin-bead media have been treated in order to produce a media capable of removing selenium without relying on reduction techniques in the system.

Table 7 shows preliminary bench-scale test results on these two media treating the wastewater at the Dumfries site. Zeolite and resin were found to remove selenium from 10.6 ppb to 6-7 and 0.91 ppb, respectively.

Table 7. Bench-Scale Test Results on Proprietary Zeolite and Resin

Column Test of Chem Treats Media						
Date	Time	Sample	Arsenic	Selenium	Thallium	Zinc
11/9/2016	15:00	Raw	63.8	10.6	0.33	13.9
11/9/2016	15:30	Resin Column Test 1	9.61	0.91	0.28	4.11
11/9/2016	15:45	Resin Column Test 2	8.00	0.91	0.26	4.22
11/9/2016	15:35	Zeolite Column Test 1	6.46	6.98	0.11	6.46
11/9/2016	15:50	Zeolite Column Test 2	5.56	6.22	0.11	3.45

3.4 Granular Activated Carbon

Introduction of granular activated carbon (GAC) as a pretreatment filtration media is a viable option, as it reduces the organic fouling potential on adsorbent and ion exchange media in the existing treatment train. While this media type cannot be effectively used to remove selenium, it can also be combined with other adsorption or ion exchange media by removing DO from water and consequently lowering the ORP level. GAC can also remove selenium that may be complexed with natural organic matter (NOM), leading to a recommendation that granular activated carbon be posed as an additional treatment step utilized to enhance selenium removal.

A bench-scale test on September 23th, 2016, conducted by ProAct on Evaluation of the Use of Adsorbent and Ion Exchange Media for the Removal of Selenium from Wastewater at the Dumfries site (Appendix E) showed that a 12x40 GAC column reduced the ORP from 131 mV down to a negative level of – 33 mV and reduced the selenium concentration from 4.8 ppb down to 1.6 ppb.

4. Recommendations

In order to fully optimize the treatment system for varying influent conditions, graduated steps towards the addition of different optimization means will be taken. The first step will be increased injection rates of ferric chloride and sodium sulfite, along with the addition of an inclined plate clarifier, deep bed sand filters and post aeration. Introduction of anionic polyacrylamide emulsion (PAM) at the chemical injection trailers may be utilized to create stronger flocs, if required.

In terms of ease to implement, secondary preference is given to addition of further media vessels on site. ASG (manganese-complexed activated alumina adsorption media) and A100 (weakly basic anion exchange resin) were found to be able to reduce selenium to a non-detection level. Depending on influent conditions, pretreatment for removal of competing anions will be required to make A100 and ASG feasible for the removal of selenium at the Dumfries site. Investigation into two proprietary zeolite and resin medias is in place as a preliminary bench-scale test has shown promising results. In the event these two proprietary media do not appear to perform satisfactorily, the final media recommendation is that GAC (12x40) media be used as an enhanced step to lower the ORP prior to AA adsorption.

5. Resources

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APPENDIX A



Carbonair

1480 County Road C West, Roseville, MN 55113

Bench-Scale Study Report

Determination of Effective Treatment Methods
for the Removal of Selenium from Wastewater
at the Dumfries, VA Site

October 30th – Rev 2

00022477

1. Objectives

The main objective of this bench-scale study is to determine the effectiveness of different filtration media with and without chemical addition in the removal of selenium from the wastewater at the Dumfries, VA site. The filtration media evaluated in this study are as follows:

- 1) Sand (0.30-0.35 mm (45x50 mesh))
- 2) Granular activated alumina (AA) (14x28 mesh)
- 3) Purolite A-100 weakly basic anion (WBA) exchange resin (16x50 mesh)

Ferric chloride (FeCl_3) was used as a flocculating agent while sodium sulfite (Na_2SO_3) was used as a reducing agent to convert selenate into selenite, the form of which can be more effectively adsorbed by iron flocs and AA.

2. Experimental Procedure

The test was divided into two parts – with and without chemical addition.

Part 1: Without Chemical Addition

Part 1 was conducted by feeding approximately 3-4 gallons of wastewater sample taken from the pond into three 2-inch diameter columns *in series* at a flow rate of ~ 400 ml/min. This feeding rate corresponds to the same hydraulic loading rate of ~ 5 gpm/ft² as that expected in the full-scale system.

The 1st column contained approximately 3-ft bed depth of sand media while the 2nd and 3rd columns contained approximately 1-ft bed depth of AA and A100, respectively. The wastewater sample was filtered through a 0.5-micron (nominal) bag filter prior to being fed through the AA column.

Part 2: With Chemical Addition

Part 2 was similar to Part 1 except that the influent sample was dosed with 50 ppmv (71 ppmw) of FeCl_3 and 66 ppmv (76 ppmw) of Na_2SO_3 prior to being fed into the 1st column. These dosages have been found to be the optimum dosages for flocculation in the full-scale operation. Additional 10 ppmw of Na_2SO_3 was added into the wastewater prior to be fed into the 0.5-micron bag filtration and AA column.

Influent and effluent samples were taken *in triplicate* and sent to a lab for analysis of selenium and other three heavy metals - arsenic, thallium, and zinc. The effluent sample from each column was taken after at least 3 liters of the wastewater had been fed through the column.

3. Experimental Results

The results from the bench-scale test can be summarized as follows:

Part 1: Without Chemical Addition

Sample	pH (s.u.)	ORP (mV)	Turbidity (NTU)
Influent	8.4	19	15.4
Sand	8.6	30	3.06
AA	9.3	46	2.84
A100	8.2	83	2.41

Sample	Selenium # 1 (ug/L)	Selenium # 2 (ug/L)	Selenium # 3 (ug/L)	Selenium (Average) (ug/L)	Discharge Limits (Monthly/Daily) (ug/L)
Influent	5.42	6.41	5.56	5.80	8 / 8

Sand	5.80	5.55	5.27	5.54	8 / 8
AA	4.37	4.09	4.66	4.37	8 / 8
A100	< 0.91	< 0.91	< 0.91	< 0.91	8 / 8

Sample	Arsenic # 1 (ug/L)	Arsenic # 2 (ug/L)	Arsenic # 3 (ug/L)	Arsenic (Average) (ug/L)	Discharge Limits (Monthly/Daily) (ug/L)
Influent	102	102	99.8	101.3	240 / 440
Sand	83.3	81.5	80.7	81.8	240 / 440
AA	4.18	4.45	4.77	4.50	240 / 440
A100	2.56	2.61	2.45	2.54	240 / 440

Sample	Thallium # 1 (ug/L)	Thallium # 2 (ug/L)	Thallium # 3 (ug/L)	Thallium (Average) (ug/L)	Discharge Limits (Monthly/Daily) (ug/L)
Influent	0.177	0.163	0.156	0.165	0.94 / 0.94
Sand	0.136	0.143	0.136	0.138	0.94 / 0.94
AA	< 0.11	< 0.11	< 0.11	< 0.11	0.94 / 0.94
A100	< 0.11	< 0.11	< 0.11	< 0.11	0.94 / 0.94

Sample	Zinc # 1 (ug/L)	Zinc # 2 (ug/L)	Zinc # 3 (ug/L)	Zinc (Average) (ug/L)	Discharge Limits (Monthly/Daily) (ug/L)
Influent	1.33	1.21	1.50	1.35	98 / 180
Sand	1.28	1.45	1.93	1.55	98 / 180
AA	4.41	2.54	2.60	3.18	98 / 180
A100	1.58	2.05	2.59	2.07	98 / 180

Part 2: With Chemical Addition

Sample	pH (s.u.)	ORP (mV)	Turbidity (NTU)
Influent	8.5	168	10.4
FeCl ₃ & Na ₂ SO ₃	6.6	165	24.8
Sand	7.0	125	1.26
Na ₂ SO ₃	7.2	116	1.26
AA	8.8	88	1.36
A100	8.5	77	1.09

Sample	Selenium # 1 (ug/L)	Selenium # 2 (ug/L)	Selenium # 3 (ug/L)	Selenium (Average) (ug/L)	Discharge Limits (Monthly/Daily) (ug/L)
Influent	5.42	6.41	5.56	5.80	8 / 8
Sand	5.41	5.49	5.66	5.52	8 / 8
AA	5.15	4.64	4.39	4.73	8 / 8
A100	< 0.91	< 0.91	< 0.91	< 0.91	8 / 8

Sample	Arsenic # 1 (ug/L)	Arsenic # 2 (ug/L)	Arsenic # 3 (ug/L)	Arsenic (Average) (ug/L)	Discharge Limits (Monthly/Daily) (ug/L)
Influent	102	102	99.8	101.3	240 / 440
Sand	5.35	5.11	5.52	5.33	240 / 440
AA	1.91	1.77	1.87	1.85	240 / 440
A100	1.78	1.83	1.87	1.83	240 / 440

Sample	Thallium # 1 (ug/L)	Thallium # 2 (ug/L)	Thallium # 3 (ug/L)	Thallium (Average) (ug/L)	Discharge Limits (Monthly/Daily) (ug/L)
Influent	0.177	0.163	0.156	0.165	0.94 / 0.94
Sand	0.146	0.142	0.145	0.144	0.94 / 0.94
AA	< 0.11	< 0.11	< 0.11	< 0.11	0.94 / 0.94
A100	< 0.11	< 0.11	< 0.11	< 0.11	0.94 / 0.94

Sample	Zinc # 1 (ug/L)	Zinc # 2 (ug/L)	Zinc # 3 (ug/L)	Zinc (Average) (ug/L)	Discharge Limits (Monthly/Daily) (ug/L)
Influent	1.33	1.21	1.50	1.35	98 / 180
Sand	1.89	2.22	2.29	2.13	98 / 180
AA	1.08	1.18	1.18	1.15	98 / 180
A100	< 0.79	< 0.79	< 0.79	< 0.79	98 / 180

4. Discussion

Selenium Removal

Without chemical addition, selenium was reduced from 5.8 ppb down to 5.54 ppb by sand filtration, and to 4.37 ppb by AA. These results suggest that only 0.26 ppb of selenium was present in the filterable particulate form, and only 1.17 ppb of selenium was adsorbable by AA. Experience indicates the adsorbable form of selenium is selenite. The remaining selenium of 4.37 ppb was able to be removed by A100 to < 0.91 ppb. We concluded this portion of the selenium is in an anionic form of selenate.

The results on selenium removal with the chemical addition appeared to be very similar to those obtained from the test without chemical addition. These results suggest that the level of chemical addition utilized for this specific test has no effect on the removal of selenium. A large amount of sludge would be generated if higher chemical injection rates were tested. Due to site constraints and equipment available at the time of testing, higher chemical injection rates could not be utilized. As a result, it was not possible to achieve lower ORP values through experimentation with higher chemical injection rates. Experience indicates that negative ORP values can convert selenate to selenite, which can improve removal efficiencies.

Arsenic Removal

Without chemical addition, arsenic was reduced from 101.3 ppb down to 81.8 ppb by sand filtration, and to 4.5 ppb by AA. These results suggest that 19.5 ppb of arsenic was present in the filterable particulate form, and 77.3 ppb of arsenic was adsorbable by AA. This form of arsenic was determined to be mostly arsenate. The remaining arsenic of 4.50 ppb was removed to 2.54 ppb by A100.

With the chemical addition, arsenic was effectively reduced from 101.3 ppb down to 5.52 ppb by chemical flocculation followed by sand filtration, and to 1.85 ppb by AA. A100 showed no significant effect on the removal of the remaining arsenic.

Thallium Removal

Without chemical addition, thallium was reduced from 0.165 ppb down to 0.138 ppb by sand filtration, and to < 0.11 ppb by AA. These results show that 0.027 ppb of arsenic was present in the filterable particulate form while the remaining thallium was adsorbable by AA.

The results on thallium removal with the chemical addition appeared to be very similar to those obtained from the test without chemical addition. These results suggest that the chemical injection rates utilized do not have an effect on the removal of thallium.

Zinc Removal

Without chemical addition, zinc was found to increase from 1.35 ppb to 1.55 and 3.18 ppb through the sand and AA columns, respectively. With the chemical addition, zinc was found to increase from 1.35 ppb to 2.13 ppb through the sand column. The increases in zinc concentration was caused by zinc that leached off of metal fittings, which were present during the test.

5. Conclusion

- 1) Of the total selenium concentration of 5.8 ppb in the wastewater at the Dumfries site, 0.26, 1.17, and 4.37 ppb of selenium is in the present forms of particulates, selenite, and selenate, respectively. Particulate selenium was removed by 0.30-0.35 mm sand filtration with a bed depth of > 3 ft. Selenite was removed by AA adsorption. Selenate was removed by A100 anion exchange resin. All the selenium was removed to a non-detectable level of < 0.91 ppb with the use of all the three treatment methods without chemical addition.
- 2) At the chemical injection rates utilized, ferric chloride as a flocculating agent at 71 ppmw along with sodium sulfite as a reducing agent at 76 ppmw added to the wastewater prior to being fed to sand filtration were found to have no effect on the removal of selenium. Neither was the additional dosing of 10 ppmw of sodium sulfite into the wastewater sample prior to being fed to the AA column found to have effect on the removal of selenium. The tested sodium sulfite dosages are not sufficient to convert selenate into selenite, the form of which can be removed by AA adsorption. A higher dose of sodium sulfite than was tested would be required to achieve the necessary reduction.
- 3) Of the total arsenic concentration of 101.3 ppb, 19.5 and 77.3 ppb of arsenic was removed by sand filtration and AA adsorption, respectively. Ferric chloride flocculation followed by sand filtration was found to be very effectively remove arsenic from 101.3 ppb down to 5.52 ppb, and further down to 1.85 ppb by AA adsorption. A100 showed no significant effect on the removal of the remaining arsenic.
- 4) Thallium was found to be reduced from 0.165 ppb down to 0.138 ppb by sand filtration, and further down to a non-detectable level of < 0.11 ppb by AA adsorption. Chemical addition showed no effect on the removal of thallium.
- 5) Zinc was found to increase through the treatment system. The increases in zinc concentration was caused by zinc that leached off of the metal fittings.

Filter Media Characteristics

TABLE 14.8 Design Features of Monomedium Filter Beds for Wastewater Treatment^a (Oaste, 1987)

Characteristic	Value	
	Range	Typical
<i>Shallow bed (stratified)</i>		
Sand		
Depth, cm (in.)	25–30 (10–12)	28 (11)
Effective size, mm	0.35–0.6	0.45
Uniformity coefficient	1.2–1.6	1.5
Filtration rate, m/h (gal/ft ² /min)	5–15 (2–6)	7 (3)
Anthracite		
Depth, cm (in.)	30–50 (12–20)	40 (16)
Effective size, mm	0.8–1.5	1.3
Uniformity coefficient	1.3–1.8	1.6
Filtration rate, m/h (gal/ft ² /min)	5–15 (2–6)	7 (3)
<i>Conventional (stratified)</i>		
Sand		
Depth, cm (in.)	50–76 (20–30)	60 (24)
Effective size, mm	0.4–0.8	0.65
Uniformity coefficient	1.2–1.6	1.5
Filtration rate, m/h (gal/ft ² /min)	5–15 (2–6)	7 (3)
Anthracite		
Depth, cm (in.)	60–90 (24–36)	76 (30)
Effective size, mm	0.8–2.0	1.3
Uniformity coefficient	1.3–1.8	1.6
Filtration rate, m/h (gal/ft ² /min)	5–20 (2–8)	10 (4)
<i>Deep bed (unstratified)</i>		
Sand		
Depth, cm (in.)	90–180 (36–72)	120 (48)
Effective size, mm	2–3	2.5
Uniformity coefficient	1.2–1.6	1.5
Filtration rate, m/h (gal/ft ² /min)	5–24 (2–10)	12 (5)
Anthracite		
Depth, cm (in.)	90–215 (36–84)	150 (60)
Effective size, mm	2–4	2.75
Uniformity coefficient	1.3–1.8	1.6
Filtration rate, m/h (gal/ft ² /min)	5–24 (2–10)	12 (5)

^aMetcalf and Eddy (1991), *Wastewater Engineering: Treatment, Disposal, Reuse*, 3rd ed., G. Tchobanoglous and F. L. Burton, eds., McGraw-Hill, Toronto, reproduced with permission of McGraw-Hill, Inc.

APPENDIX C

Pilot-Scale Study Report

**Determination of the Effectiveness of A100 Resin
for the Removal of Selenium from Wastewater
at the Dumfries, VA Site**

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1.0 Objectives

The main objective of this pilot-scale study is to determine the effectiveness of A100 weakly basic anion exchange resin at removing selenium from the wastewater at the Dumfries, VA site. Removal of other three metals of concern - arsenic, thallium, and zinc – were also studied.

2.0 Experimental Procedures

A submersible pump conveyed water from Pond D to a dewatering box. The dewatering box served as a holding tank. A small submersible pump then conveyed water from the dewatering box into a pilot test trailer at an approximate flow rate of 5 gpm.

The pilot test trailer had the following components plumbed in series: a bag filter loaded with 0.5 μm filter elements, a 14 in. diameter PC1 vessel containing activated alumina (AA) with a bed depth of 3 ft. (3.3 ft³), and a 14 in. diameter PC1 vessel containing A100 weakly basic anion exchange resin with a bed depth of 3 ft. (3.3 ft³).

The pilot test trailer effluent flowed into another dewatering box, where it was stored until authorization was given to discharge the treated water back into Pond D.

During the 4-5 day testing period, water samples were sent to an off-site lab for selenium, arsenic, thallium and zinc analysis.

3.0 Experimental Results

The analytical results from the pilot-scale test are summarized in the following tables.

Table 3.1 pH, ORP, and Turbidity (On-Site Measurements)

Date	Sampling Location	Average pH (s.u.)	Average ORP (mV)	Average Turbidity (n)
10-17-16	Influent	7.87	79.2	8.8
	Effluent	8.06	63.7	3.2
10-18-16	Influent	7.65	96.6	7.3
	Effluent	7.83	93.1	2.8
10-19-16	Influent	8.30	107.0	7.2
	Effluent	7.84	106.0	2.7

Table 3.2 Selenium

Sample #	Run Time (hr.)	Volume Treated (gal.)	Volume Treated (Bed Volumes*)	Selenium (Influent) (µg/L)	Selenium (Post Bag Filter) (µg/L)	Selenium (Post AA) (µg/L)	Selenium (Post A100) (µg/L)
1	0	0	0	11.3	10.6	7.48	0.91
2	8	2,400	96	11.0	10.8	9.36	4.94
3	16	4,800	192	11.1	11.7	9.05	7.20
4	24	7,200	288	11.1	10.6	8.90	8.95
5	32	9,600	384	11.3	11.3	9.92	8.35
6	40	12,000	480	11.1	12.6	9.54	9.08
7	48	14,400	576	11.1	11.1	9.93	10.20
8	56	16,800	672	11.3	11.0	10.80	10.20
9	64	19,200	768	11.6	11.0	9.74	9.18
10	72	21,600	864	11.8	11.6	9.80	9.72
11	80	24,000	960	11.6	11.6	10.90	10.70
12	88	26,400	1,056	11.9	10.8	10.40	10.10
13	96	28,800	1,152	11.1	12.0	10.90	9.72
14	104	31,200	1,248	10.2	11.4	11.10	11.40

* A100 and AA have the same bed volume of 3.3 ft³.

Table 3.3 Arsenic

Sample #	Run Time (hr.)	Volume Treated (gal.)	Volume Treated (Bed Volumes*)	Arsenic (Influent) (µg/L)	Arsenic (Post Bag Filter) (µg/L)	Arsenic (Post AA) (µg/L)	Arsenic (Post A100) (µg/L)
1	0	0	0	67.2	56.2	16.30	15.10
2	8	2,400	96	73.4	71.4	11.40	10.90
3	16	4,800	192	74.7	73.6	11.30	10.50
4	24	7,200	288	71.6	71.0	10.50	10.30
5	32	9,600	384	79.4	79.8	7.97	7.86
6	40	12,000	480	72.9	73.9	9.62	8.97
7	48	14,400	576	76.4	74.2	8.83	9.26
8	56	16,800	672	75.2	75.7	8.48	8.14
9	64	19,200	768	76.2	77.9	8.26	7.95
10	72	21,600	864	81.9	79.1	8.52	8.47
11	80	24,000	960	78.8	79.5	8.81	8.34
12	88	26,400	1,056	78.5	76.2	11.70	10.90
13	96	28,800	1,152	73.1	79.3	12.60	12.00
14	104	31,200	1,248	81.4	79.3	12.50	13.80

* A100 and AA have the same bed volume of 3.3 ft³.

Table 3.4 Thallium

Sample #	Run Time (hr.)	Volume Treated (gal.)	Volume Treated (Bed Volumes*)	Thallium (Influent) (µg/L)	Thallium (Post Bag Filter) (µg/L)	Thallium (Post AA) (µg/L)	Thallium (Post A100) (µg/L)
1	0	0	0	0.175	0.142	< 0.11	0.267
2	8	2,400	96	0.164	0.162	< 0.11	< 0.11
3	16	4,800	192	0.160	0.198	< 0.11	< 0.11
4	24	7,200	288	0.156	0.160	< 0.11	< 0.11
5	32	9,600	384	0.174	0.320	< 0.11	< 0.11
6	40	12,000	480	0.177	0.298	< 0.11	< 0.11
7	48	14,400	576	0.277	0.228	0.133	0.136
8	56	16,800	672	0.234	0.228	0.222	0.199
9	64	19,200	768	0.248	0.241	0.168	0.163
10	72	21,600	864	0.251	0.316	0.201	0.185
11	80	24,000	960	0.247	0.242	0.198	0.196
12	88	26,400	1,056	0.256	0.239	0.189	0.182
13	96	28,800	1,152	0.289	0.321	0.228	0.207
14	104	31,200	1,248	0.315	0.257	0.205	0.203

* A100 and AA have the same bed volume of 3.3 ft³.

Table 3.5 Zinc

Sample #	Run Time (hr.)	Volume Treated (gal.)	Volume Treated (Bed Volumes*)	Zinc (Influent) (µg/L)	Zinc (Post Bag Filter) (µg/L)	Zinc (Post AA) (µg/L)	Zinc (Post A100) (µg/L)
1	0	0	0	85.7	81.3	17.70	16.90
2	8	2,400	96	34.3	35.0	10.70	10.50
3	16	4,800	192	23.3	27.9	9.50	9.81
4	24	7,200	288	22.4	24.7	6.81	6.36
5	32	9,600	384	16.9	17.2	4.32	4.08
6	40	12,000	480	21.3	25.1	6.66	6.45
7	48	14,400	576	19.0	21.2	6.24	6.29
8	56	16,800	672	21.9	24.9	6.48	6.27
9	64	19,200	768	18.7	19.1	5.31	5.87
10	72	21,600	864	22.1	23.6	5.28	7.37
11	80	24,000	960	24.0	22.6	6.27	5.98
12	88	26,400	1,056	25.1	25.6	7.28	6.45
13	96	28,800	1,152	17.1	20.8	6.25	5.29
14	104	31,200	1,248	18.6	24.1	5.67	5.62

* A100 and AA have the same bed volume of 3.3 ft³.

4.0 Discussion

Selenium Removal

Figure 1 shows selenium plotted as a function of bed volumes (BV) treated. Figure 1 shows that no selenium was removed by the 0.5 μm (nominal) bag filter. This implies that all the selenium in the Dumfries site wastewater is either dissolved or smaller than the nominal 0.5 μm bag filter pore size.

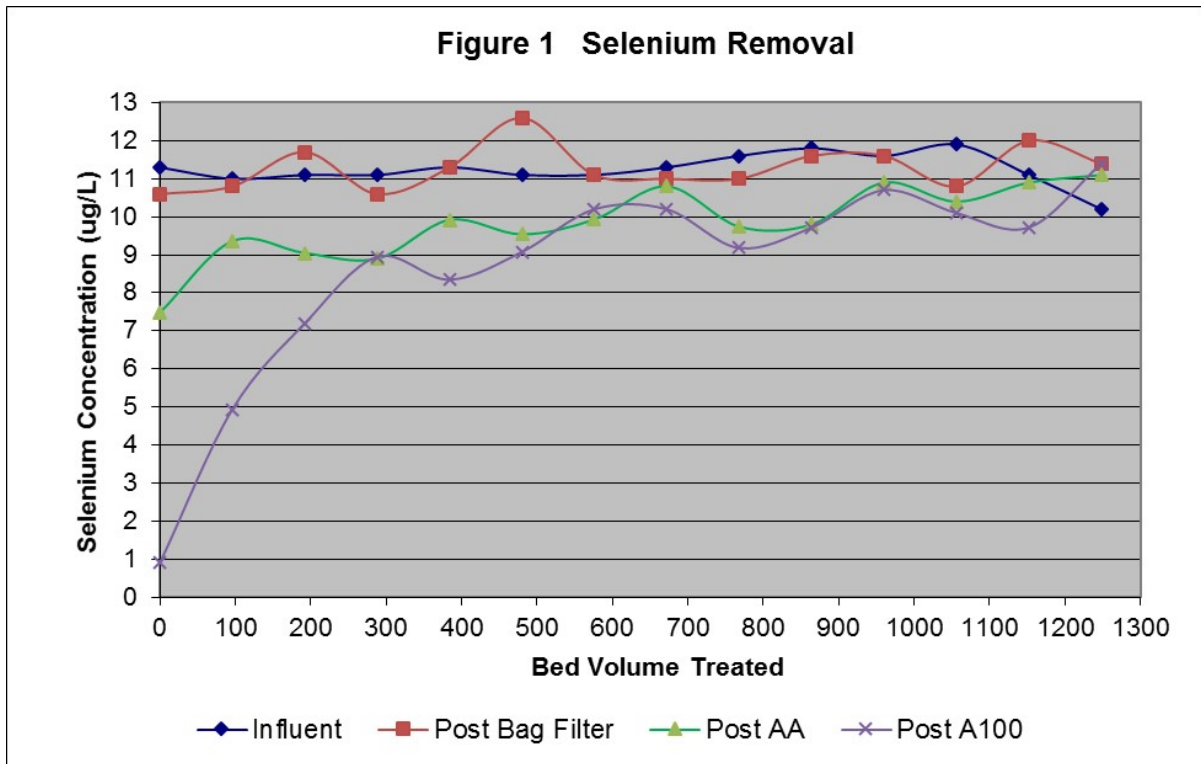


Figure 1 also shows that approximately 1-2 ppb of selenium was removed by AA. Data suggests this portion of selenium is in the form of selenite which is most readily adsorbed by AA.

Initially, selenium was removed by A100 to below the discharge limit of 8 ppb. After approximately 250 BV treated, the selenium concentration rapidly rose to the discharge limitation level and reached the post AA levels after approximately 300 BV.

Other competing anions such as sulfate, nitrate, nitrite and phosphate shorten the A100 service life. The A100 service life may be prolonged by removing those competing anions by other treatment processes before the A100 treatment. Sulfate, if present as the majority of competing anions, can be precipitated as calcium sulfate or barium sulfate using lime (calcium hydroxide), barium chloride and barium carbonate. Anion analysis of wastewater at the Dumfries site showed that no nitrate, nitrite, and phosphate were found to be present while sulfate and chloride were found to be present at 81 and 71 mg/L,

respectively. Chloride will have no effect on the selenium removal by A100 since the resin is already in the chloride form.

Arsenic Removal

Figure 2 shows arsenic plotted as a function of BV treated. Figure 2 shows that no arsenic was removed by the 0.5 μm (nominal) bag filter. This implies that all the arsenic in the Dumfries site wastewater is either dissolved or smaller than the nominal 0.5 μm bag filter pore size.

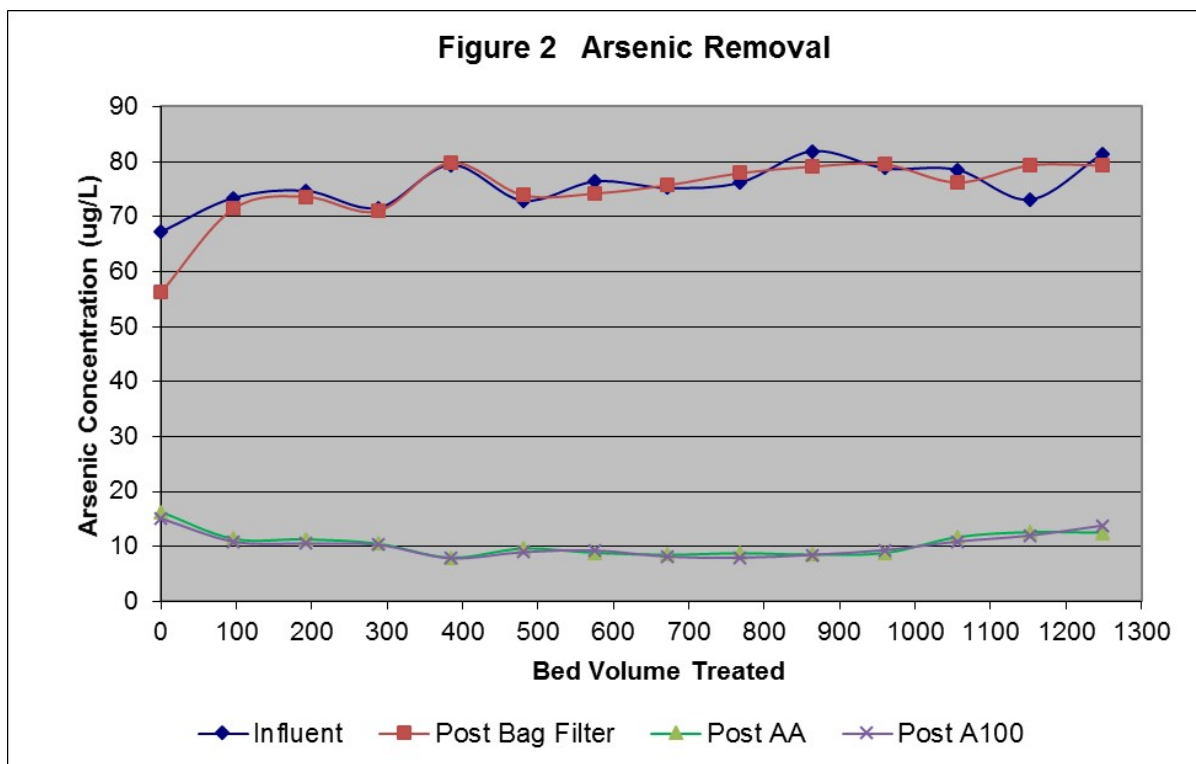


Figure 2 also shows that AA removed arsenic to below 20 ppb within the tested water volume of $\sim 1,300$ BV. Data indicates the arsenic removed by AA is in the form of arsenate.

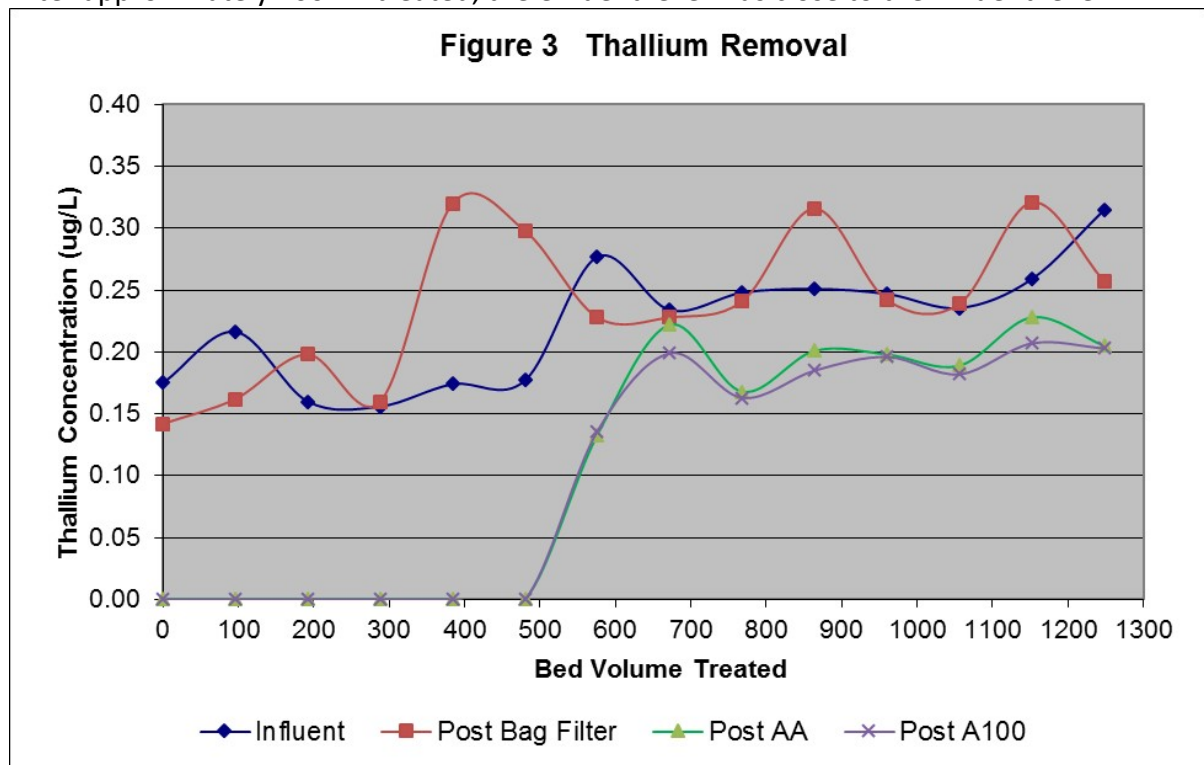
No arsenic was further removed by A100. The effluent arsenic concentration profiles from AA and A100 are almost identical.

Thallium Removal

Figure 3 shows thallium plotted as a function of BV treated. Figure 3 shows that no thallium was removed by the 0.5 μm (nominal) bag filter. This implies that all the thallium in the Dumfries site wastewater is either dissolved or smaller than the nominal 0.5 μm bag filter pore size.

Figure 3 also shows that AA removed thallium to below the detection limit of 0.11 ppb within 500 BV. Thallium is removed by AA through an adsorption process. After

approximately 500 BV treated, the effluent thallium concentration from AA rose rapidly. After approximately 700 BV treated, the effluent level was close to the influent level.



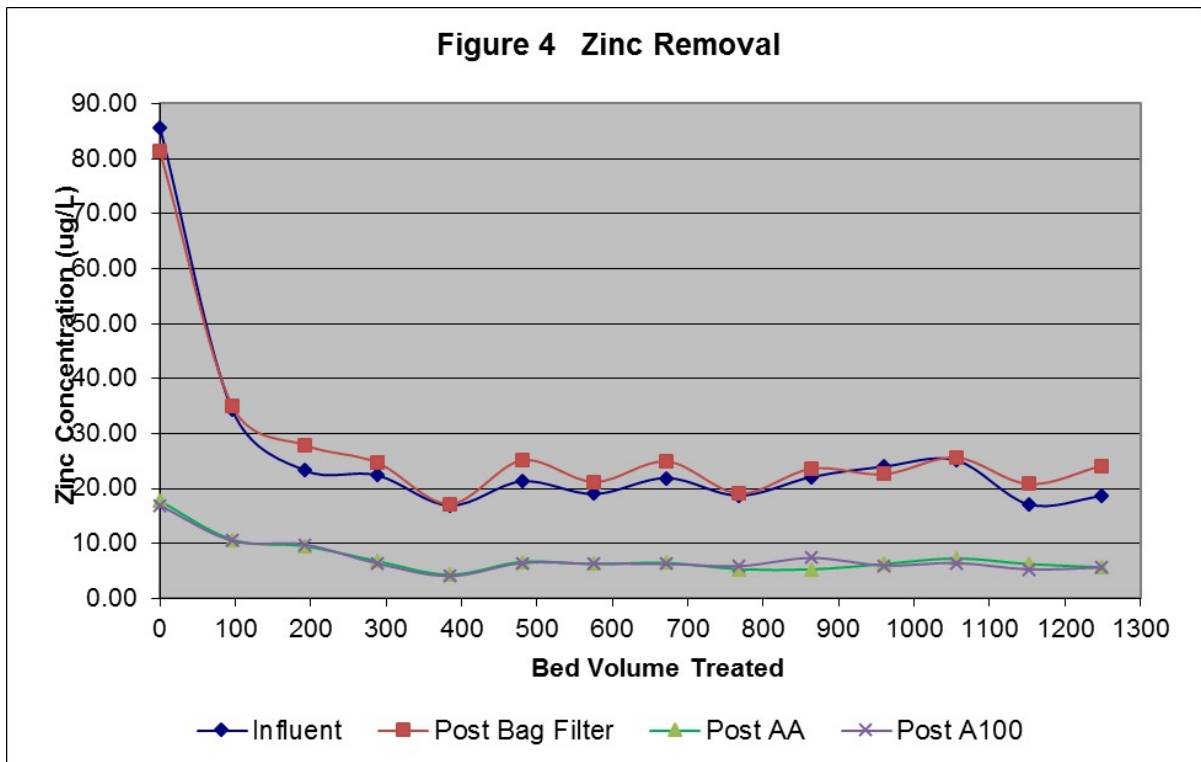
No thallium was further removed by A100. The effluent thallium concentration profiles from AA and A100 are almost identical.

Zinc Removal

Figure 4 shows zinc plotted as a function of BV treated. Figure 4 shows that no zinc was removed by the 0.5 μm (nominal) bag filter. This implies that all the zinc in the Dumfries site wastewater is either dissolved or smaller than the nominal 0.5 μm bag filter pore size.

Figure 4 also shows that AA removed zinc all the time to below 20 ppb and most of the time to below 10 ppb within the tested water volume of 1,300 BV. Zinc is removed by AA through an adsorption process.

No zinc was further removed by A100. The effluent zinc concentration profiles from AA and A100 are almost identical.



5.0 Conclusion

- 1) Without removing competing anions such as sulfate, nitrate, nitrite and phosphate before A100 treatment, A100 preceded by AA was found to be able to remove selenium to 8 ppb within 250 bed volumes. An absence of competing ions is required for A100 to be an economically viable treatment option.
- 2) The A100 service life can be prolonged by chemical precipitation or membrane filtration pretreatment to remove competing anions.
- 3) Arsenic in the Dumfries site wastewater was determined to be in the form of arsenate which is most readily removed by AA. No AA exhaustion was observed within the tested water volume of 1,300 BV. A100 had no effect on arsenic removal.
- 4) Thallium was removed by AA to below the detection limit of 0.11 ppb within 500 BV treated. The AA effluent thallium concentration rose rapidly to near the influent level at approximately 700 BV treated. A100 had no effect on thallium removal.
- 5) Zinc was removed by AA all the time to below 20 ppb and most of the time to below 10 ppb within the tested water volume of 1,300 BV. A100 had no effect on zinc removal.

APPENDIX D

Pilot-Scale Study Report

Determination of the Effectiveness of ASG AM Media
for the Removal of Selenium from Wastewater
at the Dumfries, VA Site

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1.0 Objectives

The main objective of this pilot-scale study is to determine the effectiveness of ASG AM Media at removing selenium from the wastewater at the Dumfries, VA site. Removal of other three metals of concern - arsenic, thallium, and zinc – were also studied. ASG AM media is derived from activated alumina and complexed with manganese. ASG Media remove selenium from water by reducing the oxidation state of selenium from selenate to selenite and adsorbing selenite onto its surface.

2.0 Experimental Procedures

A submersible pump conveyed water from Pond D to a dewatering box. The dewatering box served as a holding tank. A small submersible pump then conveyed water from the dewatering box into a pilot test trailer at an approximate flow rate of 5 gpm.

The pilot test trailer had the following components plumbed in series: a bag filter loaded with a 0.5 μm filter element, a 14 in. diameter PC1 vessel containing activated alumina (AA) with a bed depth of 3 ft. (3.3 ft^3), and a 14 in. diameter PC1 vessel containing ASG AM media with a media volume of 2 ft.

The pilot test trailer effluent flowed into another dewatering box, where it was stored until authorization was given to discharge the treated water back into Pond D.

During a week of testing period, water samples were sent to an off-site lab for selenium, arsenic, thallium and zinc analysis.

3.0 Experimental Results

The analytical results from the pilot-scale test are summarized in the following tables.

Table 3.1 pH, ORP, and Turbidity (On-Site Measurements)

Date	Sampling Location	Average pH (s.u.)	Average ORP (mV)	Average Turbidity (NTU)
11-7-16	Influent	6.57	102	7.82
	Post Bag	6.94	86.1	6.95
	Post AA	7.03	75.7	3.48
	Post ASG	6.83	78.6	1.9
11-8-16	Influent	7.12	87	6.31
	Post Bag	7.15	80.9	6.79
	Post AA	7.06	78.1	2.64
	Post ASG	6.80	75.6	1.8
11-9-16	Influent	7.09	61.38	5.0
	Post Bag	7.17	62.15	5.08
	Post AA	7.24	60.62	2.01
	Post ASG	7.21	65.46	1.51

11-10-16	Influent	6.61	31.6	5.18
	Post Bag	6.89	28.3	5.04
	Post AA	7.02	29.0	1.94
	Post ASG	7.12	37.6	1.36
11-11-16	Influent	6.79	18.22	6.48
	Post Bag	7.1	13.78	5.34
	Post AA	7.09	11.78	1.76
	Post ASG	7.26	12.67	1.27

Table 3.2 Selenium

Sample #	Run Time (hr.)	Volume Treated (gal.)	Volume Treated (Bed Volume*)	Selenium (Influent) (µg/L)	Selenium (Post Bag Filter) (µg/L)	Selenium (Post AA) (µg/L)	Selenium (Post ASG) (µg/L)
1	0	0	0	10.10	10.5	5.1	0.00
2	8	2,690	108	10.30	9.75	5.94	
			179				7.18
3	16	4,550	182	11.10	10.2	7.14	
			303				7.34
4	24	6,400	256	10.90	10.5	7.79	
			427				7.16
5	32	8,560	342	11.40	10.6	7.57	
			571				7.16
6	40	10,730	429	10.50	10.4	6.98	
			715				7.10
7	48	12,880	515	10.50	10.3	8.09	
			859				7.01
8	56	15,180	607	10.30	9.9	6.71	
			1,012				7.50
9	64	17,490	700	10.7	11.6	7.59	
			1,166				6.70
10	72	19,760	790	10.7	11.2	7.67	
			1,317				6.94
11	80	21,490	860	11.1	10.1	7.84	
			1,433				7.72
12	88	24,160	966	10.6	11.1	7.52	
			1,610				8.03
13	96	26,710	1,068	10.7	10.7	8.24	
			1,780				6.71
14	104	28,910	1,156	10.1	10.5	7.9	
			1,927				7.37

* ASG AM and AA have the bed volume of 3.3 and 2 ft³, respectively.

Table 3.3 Arsenic

Sample #	Run Time (hr.)	Volume Treated (gal.)	Volume Treated (Bed Volume*)	Arsenic (Influent) (µg/L)	Arsenic (Post Bag Filter) (µg/L)	Arsenic (Post AA) (µg/L)	Arsenic (Post ASG) (µg/L)
1	0	0	0	64.20	60.4	9.45	5.20
2	8	2,690	108	73.60	73.2	9.92	
			179				7.04
3	16	4,550	182	76.20	73.0	9.8	
			303				7.44
4	24	6,400	256	69.20	65.6	9.43	
			427				6.95
5	32	8,560	342	75.50	71.3	7.57	
			571				5.34
6	40	10,730	429	63.80	66.3	8.51	
			715				6.70
7	48	12,880	515	62.20	62.4	8.57	
			859				6.26
8	56	15,180	607	63.80	63.7	8.25	
			1,012				6.24
9	64	17,490	700	64.9	64.7	8.83	
			1,166				6.39
10	72	19,760	790	69.8	70.6	9.11	
			1,317				5.97
11	80	21,490	860	67.8	67.3	10.1	
			1,433				6.3
12	88	24,160	966	65.8	65.2	7.44	
			1,610				4.83
13	96	26,710	1,068	62.5	52.5	8.11	
			1,780				4.74
14	104	28,910	1,156	63.5	63.8	7.49	
			1,927				4.24

* ASG AM and AA have the bed volume of 3.3 and 2 ft³, respectively.

Table 3.4 Thallium

Sample #	Run Time (hr.)	Volume Treated (gal.)	Volume Treated (Bed Volume*)	Thallium (Influent) (µg/L)	Thallium (Post Bag Filter) (µg/L)	Thallium (Post AA) (µg/L)	Thallium (Post ASG) (µg/L)
1	0	0	0	0.286	0.272	0.000	0.000
2	8	2,690	108	0.275	0.280	0.000	
			179				0.000
3	16	4,550	182	0.331	0.315	0.000	
			303				0.000
4	24	6,400	256	0.331	0.314	0.000	
			427				0.000
5	32	8,560	342	0.369	0.336	0.135	
			571				0.000
6	40	10,730	429	0.356	0.343	0.141	
			715				0.000
7	48	12,880	515	0.336	0.335	0.164	
			859				0.000
8	56	15,180	607	0.335	0.341	0.177	
			1,012				0.000
9	64	17,490	700	0.329	0.330	0.187	
			1,166				0.000
10	72	19,760	790	0.335	0.337	0.191	
			1,317				0.000
11	80	21,490	860	0.634	0.623	0.701	
			1,433				0.411
12	88	24,160	966	0.359	0.378	0.210	
			1,610				0.000
13	96	26,710	1,068	0.347	0.343	0.223	
			1,780				0.000
14	104	28,910	1,156	0.34	0.34	0.257	
			1,927				0.000

* ASG AM and AA have the bed volume of 3.3 and 2 ft³, respectively.

Table 3.5 Zinc

Sample #	Run Time (hr.)	Volume Treated (gal.)	Volume Treated (Bed Volume*)	Zinc (Influent) (µg/L)	Zinc (Post Bag Filter) (µg/L)	Zinc (Post AA) (µg/L)	Zinc (Post ASG) (µg/L)
1	0	0	0	28.40	30.20	4.37	3.85
2	8	2,690	108	17.20	19.20	3.23	
			179				2.01
3	16	4,550	182	14.10	16.10	2.77	

			303				1.98
4	24	6,400	256	11.40	13.70	1.80	
			427				1.93
5	32	8,560	342	9.67	11.60	1.57	
			571				1.13
6	40	10,730	429	9.99	20.80	3.82	
			715				3.89
7	48	12,880	515	10.70	14.30	2.78	
			859				2.35
8	56	15,180	607	12.50	13.10	3.42	
			1,102				3.89
9	64	17,490	700	8.46	11.00	1.37	
			1,166				1.05
10	72	19,760	790	8.67	11.3	1.28	
			1,317				1.33
11	80	21,490	860	9.44	11.0	67.1	
			1,433				0.96
12	88	24,160	966	9.38	10.7	0.97	
			1,610				132
13	96	26,710	1,068	8.51	9.29	1.25	
			1,780				0.79
14	104	28,910	1,156	8.35	10.4	1.07	
			1,927				34.2

* ASG AM and AA have the bed volume of 3.3 and 2 ft³, respectively.

4.0 Discussion

Selenium Removal

Figures 1(a) and 1(b) show selenium concentrations plotted as a function of volumes treated in thousand gallons and bed volumes (BV) treated, respectively. Figures 1(a) and 1(b) shows that no significant selenium was removed by the 0.5 µm (nominal) bag filter. This implies that all the selenium in the Dumfries site wastewater is either dissolved or smaller than the nominal 0.5 µm bag filter pore size.

Figure 1(a) Selenium Removal

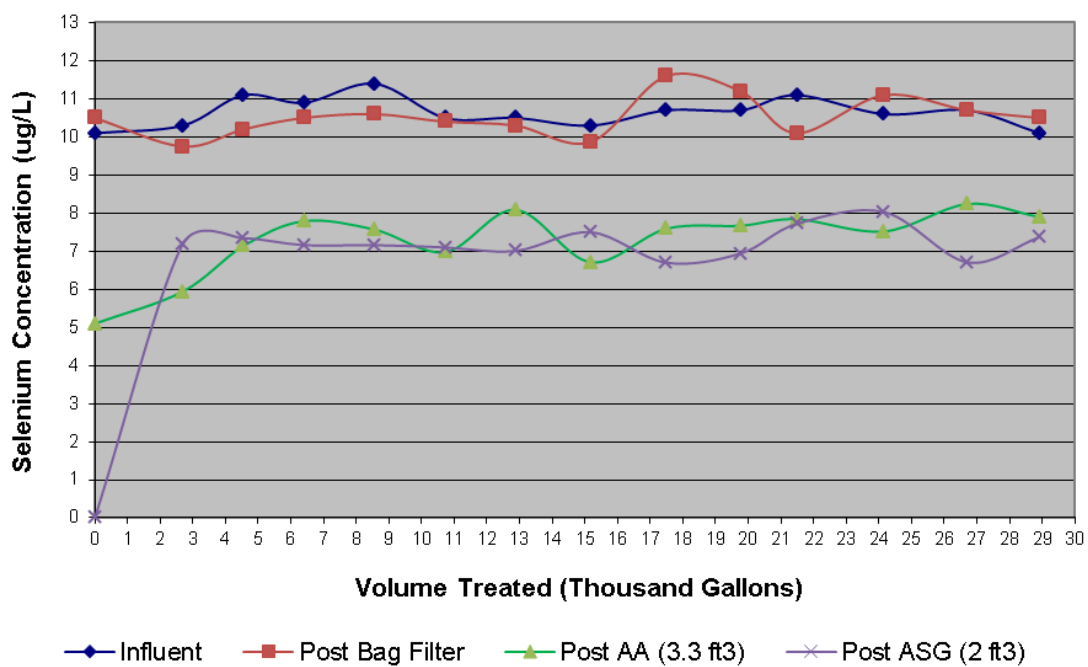
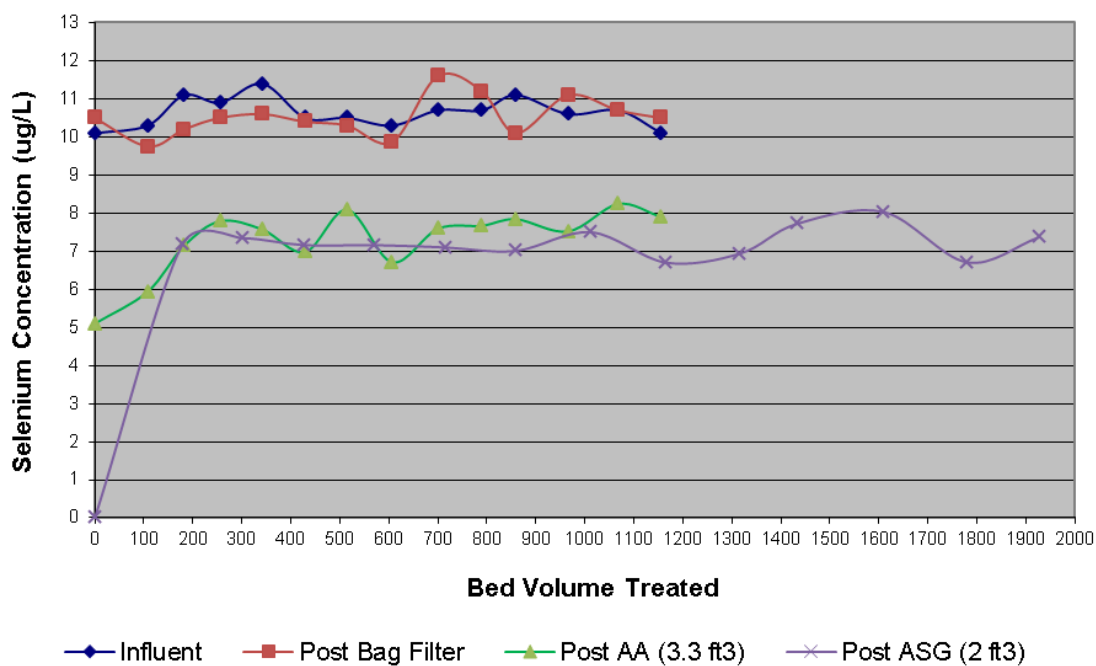


Figure 1(b) Selenium Removal

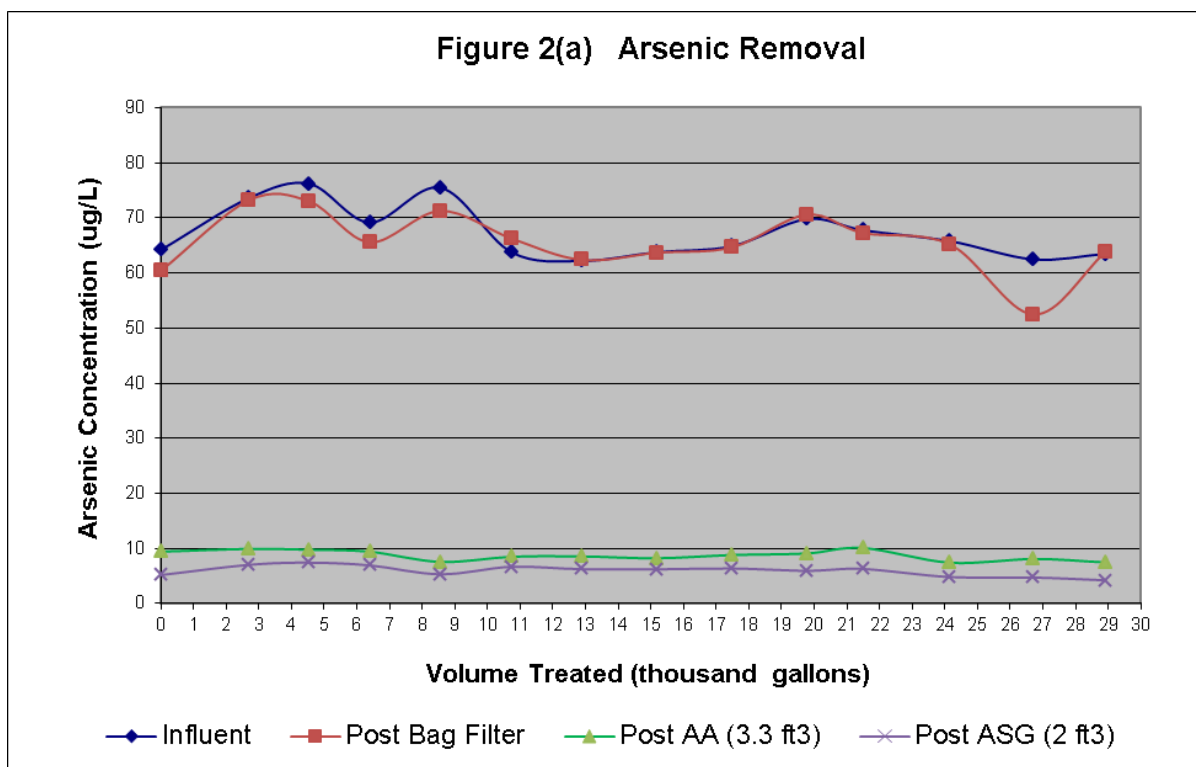


Figures 1(a) and 1(b) also show that approximately 2-5 ppb of selenium was removed by AA. Data suggests this portion of selenium is in the form of selenite which is most readily adsorbed by AA. Selenium was treated by AA alone down to below 8 ppb within the treated water volume of 600 BV at pH's of 6.5-7.2 s.u. and ORP's of < 90 mV. Figures 1(a) and 1(b) suggest that it may be beneficial to maintain the pH and ORP in these ranges in the full-scale operation.

Initially, selenium was removed by ASG to a non-detectable level. The selenium concentration rapidly rose to reach the post AA levels after approximately 100 BV. These results suggest that ASG lost its ORP reducing power very rapidly. In order for ASG to be a good adsorbent media for treating the wastewater at the Dumfries site pretreatment of other competing ions, mainly sulfate, will be required.

Arsenic Removal

Figures 2(a) and 2(b) show arsenic concentrations plotted as a function of volumes treated in thousand gallons and bed volumes (BV) treated, respectively. Figures 2(a) and 2(b) show that no arsenic was removed by the 0.5 μ m (nominal) bag filter. This implies that all the arsenic in the Dumfries site wastewater is either dissolved or smaller than the nominal 0.5 μ m bag filter pore size.



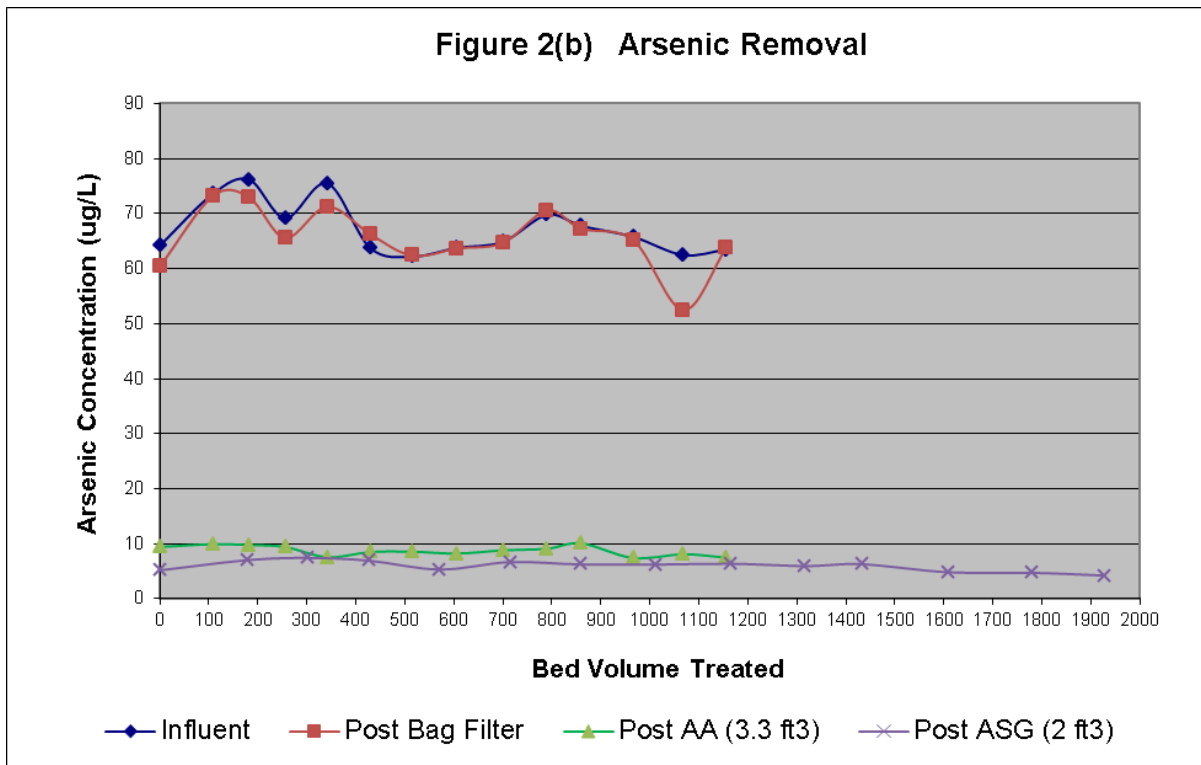


Figure 2(b) also shows that AA removed arsenic to below 10 ppb within the tested water volume of ~ 1,200 BV. Data suggests the arsenic removed by AA is in the form of arsenate. A small amount of arsenic was further removed by ASG.

Thallium Removal

Figures 3(a) and 3(b) show thallium concentrations plotted as a function of volumes treated in thousand gallons and bed volumes (BV) treated, respectively. Figures 3(a) and 3(b) shows that no thallium was removed by the 0.5 μ m (nominal) bag filter. This implies that all the thallium in the Dumfries site wastewater is either dissolved or smaller than the nominal 0.5 μ m bag filter pore size.

Figure 3 also shows that AA removed thallium to below the detection limit of 0.11 ppb within 250 BV. This data shows thallium to be removed by AA through an adsorption process. After approximately 250 BV treated, the effluent thallium concentration from AA rose sharply to approximately 50% of the influent concentration level.

Thallium was further removed by ASG to below the detection limit of 0.11 ppb within approximately 2,000 BV treated except a spike at approximately 1,400 BV. The cause of the spike has not been determined.

Figure 3(a) Thallium Removal

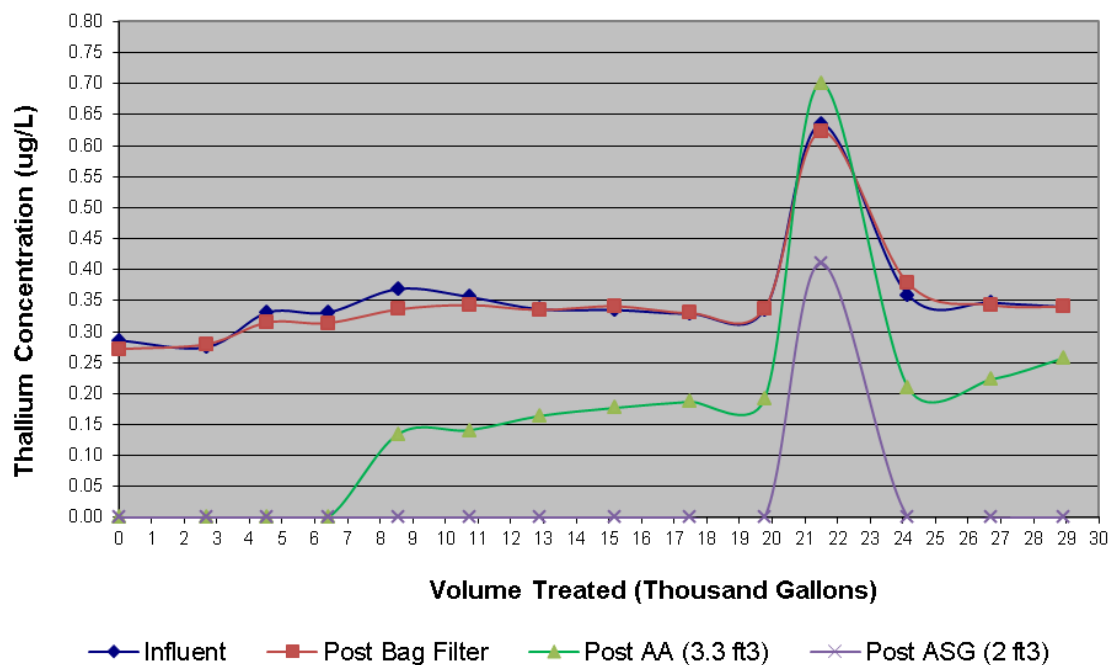
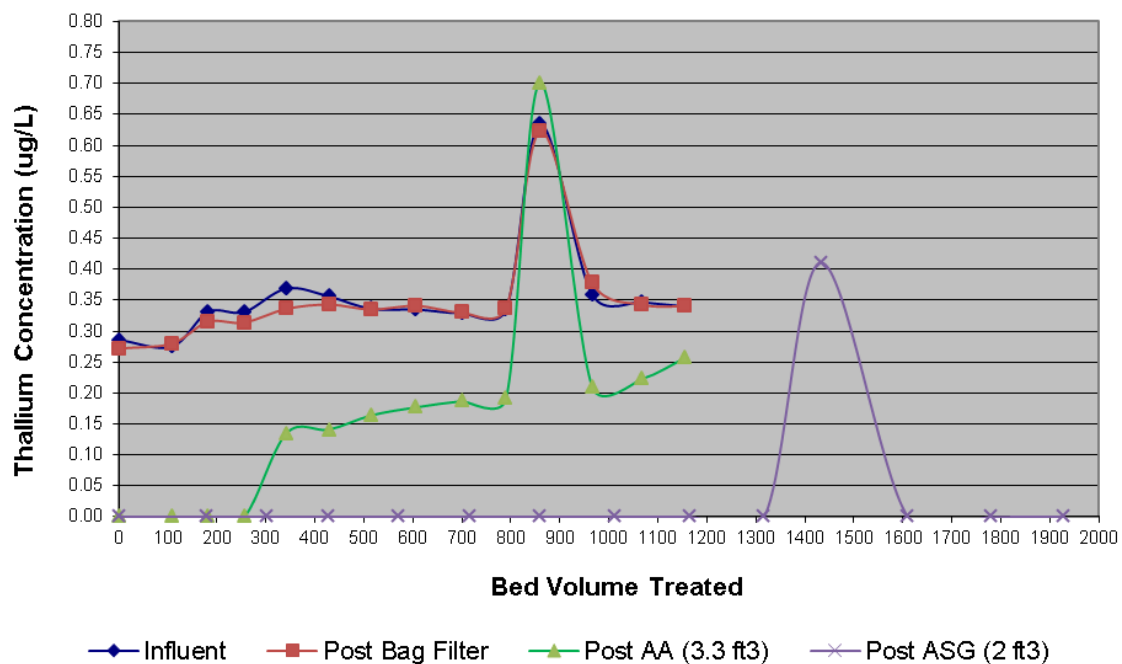


Figure 3(b) Thallium Removal

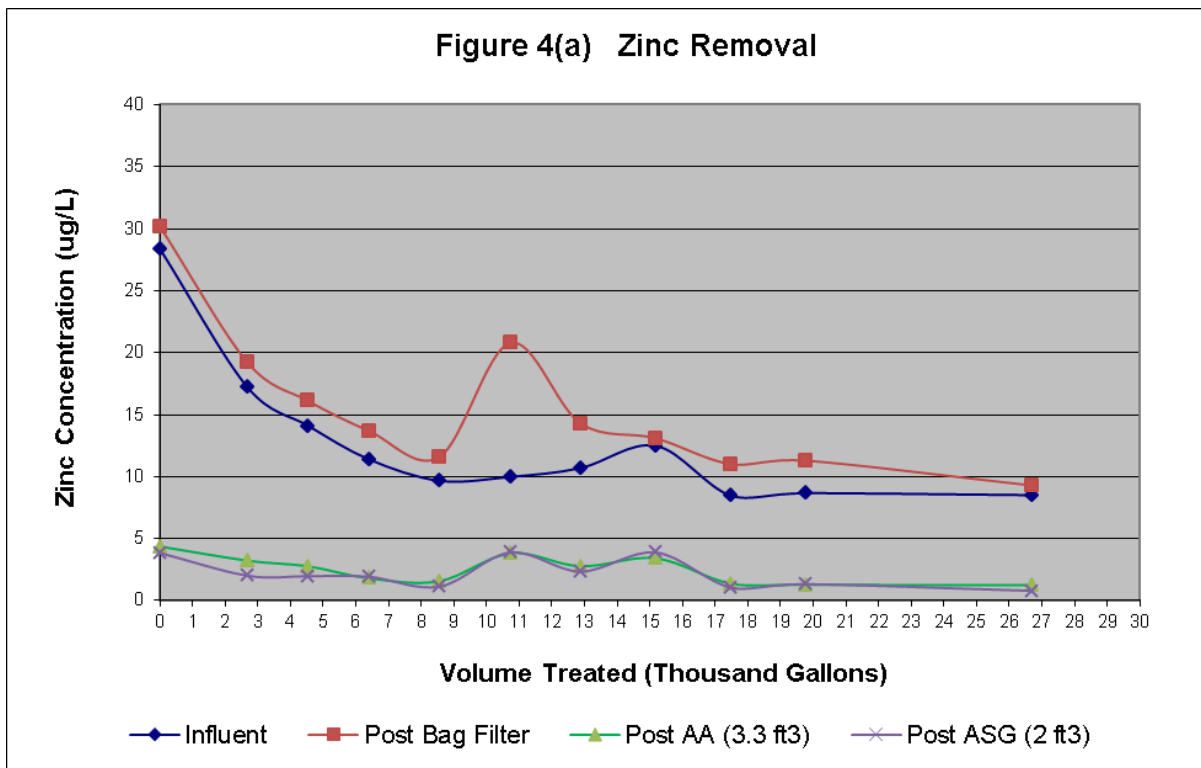


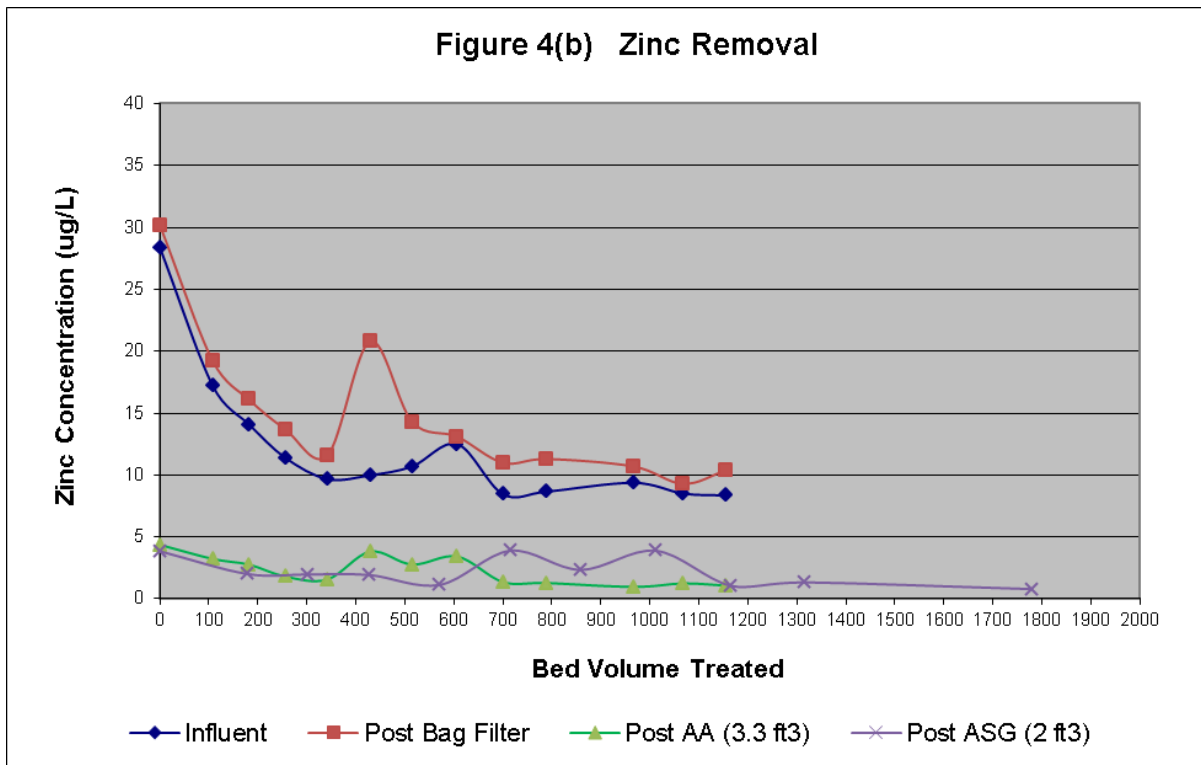
Zinc Removal

Figures 4(a) and 4(b) show zinc concentrations plotted as a function of volumes treated in thousand gallons and bed volumes (BV) treated, respectively. During the test, Samples # 11, 12, and 14 showed unreasonably high spikes in zinc concentration after AA and ASG and are not included in Figures 4(a) and 4(b). The cause of these spikes has not been determined.

Figures 4(a) and 4(b) show that the zinc concentrations after passing through the bag filter were higher than those in the influent stream. This result suggests that there was some zinc leaching from the bag filter unit.

Figures 4(a) and 4(b) also shows that AA removed zinc to below 5 ppb within the tested water volume of 1,200 BV. Zinc is believed to be removed by AA through an adsorption process. No zinc was further removed by ASG. The effluent zinc concentration profiles from AA and A100 are almost identical.





5.0 Conclusion

- 1) Selenium was removed by AA alone down to below 8 ppb within the treated water volume of 1,200 BV at pH's of 6.5-7.2 s.u. and ORP's of < 90 mV. It is believed to be beneficial to maintain the pH and ORP in these ranges in the full-scale operation.
- 2) Selenium was initially removed by ASG to a non-detectable level. The effluent concentration rapidly rose to reach the post AA levels after approximately 100 BV. Depending on influent conditions, in order for ASG to be a good adsorbent media for the removal of selenium from the wastewater at the Dumfries site, pretreatment and removal of competing ions is required.
- 3) Arsenic in wastewater at the Dumfries site is believed to be in the form of arsenate which is most readily removed by AA. No AA exhaustion was observed within the tested water volume of 1,200 BV. No arsenic was further removed by ASG.
- 4) Thallium was removed by AA to below the detection limit of 0.11 ppb within 250 BV treated. After approximately 250 BV treated, the effluent thallium concentration from AA rose sharply to approximately 50% of the influent concentration level. ASG appears to be a good adsorbent media for the removal of thallium. Thallium was removed by ASG to below the detection limit of 0.11 ppb within the treated water volume of approximately 2,000 BV.
- 5) Pilot scale testing indicated that there appeared to be some zinc leaching from the bag filter unit. This may not be a concern during full scale treatment as this

bag filter unit is only used for testing. Zinc was removed by AA to below 5 ppb within the treated water volume of 1,200 BV. No zinc was further removed by ASG.



Carbonair

1480 County Road C West, Roseville, MN 55113

APPENDIX E

Bench-Scale Study Report

Evaluation of the Use of Adsorbent and Ion Exchange Media
for the Removal of Selenium from Wastewater
at the Dumfries, VA Site

November 30th, 2016 – Rev 1

00022506

1. Objectives

The main objective of this bench-scale study is to determine the feasibility of the use of different adsorbent and ion exchange (IX) media as a polishing step for the removal of *residual selenium in the final effluent from the wastewater treatment system* at the Dumfries, VA site. The adsorbent media evaluated in this study are as follows:

- 1) Purolite A-100 weakly basic anion (WBA) exchange resin
- 2) Purolite FerriX A33E hydrated iron oxide resin
- 3) 12x40 granular activated carbon (GAC)
- 4) Granular activated alumina (AA) along with sodium sulfite addition

A-100 resin is expected to remove anionic selenium by means of ion exchange. FerriX resin is expected to remove selenium by means of exchange and adsorption. GAC is expected to remove selenium that may be complexed with natural organic matter (NOM). The small GAC particle size of 12x40 is also an excellent particulate filter that is expected to remove selenium in particulate forms. Sodium sulfite addition is used to convert residual selenate into selenite that can be more effectively removed by AA.

2. Experimental Procedure

The test was conducted by feeding approximately 1,000 ml of water sample into each of four 1-inch diameter columns at a flow rate of ~ 100 ml/min. Each column contains approximately 1-ft bed depth of each adsorbent media mentioned above. The feeding rate of 100 ml/min corresponds to the same hydraulic loading rate of ~ 5 gpm/ft² as that expected in the full-scale system. The water sample was dosed with sodium sulfite at 1 ppm prior to being fed into the AA column. Influent and effluent samples were taken and sent to a lab for analysis of total selenium using Method 200.8 ICPMS.

3. Experimental Results

The results from the bench-scale test are summarized as follows:

Sample	Mesh Size	pH (s.u.)	ORP (mV)	Selenium Concentration (ppb)	Selenium Reduction (ppb)
Influent	NA	6.70	131	4.8	0
A100	16x50	7.05	160	0.17	4.63
FerriX	16x50	7.38	105	0.33	4.47
GAC	12x40	9.52	-33	1.6	3.2
Sulphite & AA	14x28	9.62*	26*	1.4	3.4

* Prior to AA adsorption, the pH and ORP of the sample dosed with 1 ppm of sodium sulfite was measured to be 7.60 and 111 mV, respectively.

4. Discussion

Experience suggests the selenium reduction of 3.2 ppb through the 12x40 GAC column is a result mostly from particulate filtration since 12x40 GAC has very little ion exchange capacity, but rather acts as a particulate filter. This result implies that approximately 3.2 ppb of selenium in the treatment system effluent was in the form of submicron particulates (colloids) that had passed through the 1-micron (high efficiency) bag filters in the treatment system.

The selenium reduction of 3.4 ppb by the 1-ppm sulphite addition and AA is theorized to result from particulate filtration and adsorption. When comparing the difference in selenium reductions through the GAC and AA columns, we conclude that only 0.2 ppb of selenium was converted to selenite - the only form of selenium that can be effectively removed by AA adsorption. This suggests the remaining selenium concentration of 1.4 ppb to be in the selenate form, of which the ORP cannot be reduced by sulfite. It can also be concluded that no significant amount of residual

selenium was present as NOM-complexed selenium since AA has very little adsorptive capacity for NOM and there is very small difference in selenium reduction between GAC and AA.

Both A100 and FerriX media were found to remove the residual selenium to very low levels at 0.17 and 0.33 ppb, respectively. The mechanism for removal of selenium by A100 is by means of particulate filtration and IX, while FerriX removes selenium by means of all the three mechanisms – particulate filtration, IX, and adsorption. This data suggests A100 performed slightly better than FerriX, which can be because of its higher ion exchange capacity.

Taking all the test results into account, it can be concluded that of the total selenium concentration of 4.8 ppb, approximately 3.2 and 1.6 ppb of selenium are likely to be in the forms of colloidal particulates and anions, respectively.

5. Conclusion

All the tested adsorbent and IX media appeared to be able to further remove residual colloidal selenium through a filtration process during the short-term bench-scale test. However, the colloidal particulates are expected to break through the media quickly. In order to further remove residual colloidal selenium in the full-scale system, a **deep-bed** filtration with a bed depth of at least 3 ft and periodical backwashing is recommended. Among all the tested media, 12x40 GAC is least expensive and believed to be a better particulate filtration media than A100 and FerriX resins due to its amorphous shape as compared to the round resin media. An alternative to 12x40 GAC is a glass filter media - FilterGlass (<http://blog.intheswim.com/pool-filter-sand-alternatives>). This glass filter media is comparable to a diatomaceous earth (DE) filter that can remove particles as small as bacteria.

Anionic exchange using A100 or FerriX to polish residual selenium will be required in case the selenium discharge limit is still not achievable by the deep-bed filtration.